Africa Research in Sustainable Intensification for the Next Generation

Sustainable Intensification of Key Farming Systems in the Sudan and Guinea Savannas of West Africa

Technical Report,
01 October 2019 – 31 March 2020

Submitted to
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CGIAR FEED THE FUTURE The U.S. Government's Global Hunger & Food Security Initiative USAID FROM THE AMERICAN PEOPLE

The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-in-development projects supported by the United States Agency for International Development (USAID) as part of the U.S. Government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment.

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

IFPRI

IITA Transforming African Agriculture

Africa RISING appreciates support from the American people delivered through the USAID Feed the Future initiative. We also thank farmers and local partners at all sites for their contributions to the program.

Contents

Partners and their roles

Name	**Abbreviation**	**Ghana**	**Mali**	**Role/responsibility**
Government Ministries & Entities				
Ministry of Food and Agriculture	MoFA	+		Scaling-out SI technologies and establishment of R4D platforms
Ministry of Health (Ghana Health Services)	MoH (GHS)	+		Household nutrition R4D with UDS and IITA; Assist with training of women’s groups on nutrition education, data collection, & compilation of reports on activities
Ghana Irrigation Development Authority	GIDA	+		Potential scaling partner for irrigation technologies with IWMI
Veterinary Services Division	VSD	+		Animal health, capacity building for community health workers with animal research
Institut d’Economie Rurale	IER		+	Socioeconomic and on-farm studies with ICRISAT
Regional Direction of Agriculture in Sikasso	DRA-Sikasso		+	Scale-out provision of secondary data on socioeconomics
Academic/National Research Institutions				
University for Development Studies	UDS	+		Research on livestock nutrition and human nutrition, graduate training, and R4D
Science and Technology Policy Research Institute	STEPRI	+		Policy review and analysis
Institut Polytechnique Rural de Formation et de Recherche Appliquée Katibougou	IPR-IFRA		+	Polytechnic for rural education and applied research
Kwame Nkrumah University of Science and Technology	KNUST	+		Graduate student training, research on soil water dynamics
Animal Research Institute	ARI	+		R4D on livestock production (sheep and goats) with ILRI
International Research Institutions				
International Crops Research Institute for the Semi-arid Tropics	ICRISAT	+	+	Sorghum/millet and groundnut R4D with IITA and SARI
International Food Policy Research Institute	IFPRI	+	+	Surveys, and monitoring and evaluation
The World Vegetable Center	WorldVeg	+	+	Lead R4D on vegetable production systems
International Institute of Tropical Agriculture	IITA	+	+	Project coordination and R4D research on cereal–legumes

Name	Abbreviation	Ghana	Mali	Role/responsibility
International Livestock Research Institute	ILRI	+	+	Lead R4D on livestock, especially ruminants
International Water Management Institute	IWMI	+		Lead R4D on water management
Wageningen University, The Netherlands	WUR	+	+	R4D on farming systems and graduate training
International Center for Tropical Agriculture	CIAT	+		Research on land and soil management
Non-governmental Organizations				
Centre d'Appui a l'Autopromotion pour le Développement	CAAD		+	Scaling out groundnut technologies. Assisting implementation of animal health and fattening program by ILRI and IER
Fédération Nationale pour l'Agriculture Biologique et Équitable	FENABE		+	Scaling-out, capacity building, community mobilization, on-farm research
Association Malienne d'Eveil et de Développement Durable	AMEDD		+	On-farm field trials and household nutrition studies with ICRISAT
Le Groupe de Recherches d'Actions et d'Assistance pour le Développement Communautaire	GRAADCOM		+	Scaling out groundnut technologies. Assisting with the implementation of animal health and fattening program by ILRI and IER
CARE International	CARE-MALI		+	Disseminate Africa RISING validated technologies in 12 watersheds that constitute 82 villages in Mopti region
Private Organizations and Development Projects				
Community-based Organizations	CBOs	+	+	On-farm implementation of R4D activities
Peace Corps	Peace Corps	+		Introduce Africa RISING technologies to communities they work in
Seed Producers Association of Ghana	SEEDPAG	+		Seed production and training of farmers for quality declared seed
WorldCover	WorldCover	+		Indexed based agricultural insurance. Co-sharing of farmers in some communities provides synergies.
Feed the Future Innovation Labs				
Sustainable Intensification Innovation Lab	SIIL	+		Co-share materials, concepts, and approaches to conducting research, e.g., use of the sustainable intensification framework
Soybean Innovation Lab	SIL	+		Sharing knowledge and approaches towards postharvest mechanization in communities

Name	Abbreviation	Ghana	Mali	Role/responsibility
Innovation Lab for Legume Systems Research	ILLSR	+		Acting as liaison between the Mission Office and the Innovation lab and conducting joint research activities
Innovation Lab for Small Scale Irrigation	ILSSI	+		Co-location of sites with Africa RISING work and sharing knowledge, approaches, sites, and personnel, e.g., with IWMI

Summary

This report provides feedback on implemented work and achievements of partner activities mapped out against outputs and outcomes in the Phase 2 project logframe for October 2019 - March 2020 for the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) project in West Africa (Ghana and Mali).

Ghana and Mali cross-country summary

1. **Internally commissioned external project evaluation:** A three-member review team successfully conducted an evaluation of the Africa RISING Project. This review team and was composed of Christine Negra (Team leader, PhD, Plant and Soil Science), Mark Powell (Team member, Professor, Soil Science), and Nancy McCarthy (Team member, PhD, Agriculture and Resource Economics). In Ghana, the project evaluation was conducted from 16 to 21 September 2019 while in Mali it was conducted from 23 to 27 September 2019. The review team released a final report that can be found at this link: http://africa-rising-wiki.net/images/8/89/AR_Eval_Final_Report_7_April_2020.pdf
2. **West Africa handbook:** A "Handbook of agricultural sustainable intensification approaches for farmers in West Africa" has been developed. Various partners continue to contribute to the Handbook and a sample of the progress of the Handbook can be accessed here: https://docs.google.com/document/d/1HaMpUNUxNxiu8yLDvP2jCZ-gXiHwkGRynMd2J3Q67Jw/edit#
3. **Joint harmonization papers:** After a successful program-wide exchange visit in June 2019, a series of joint harmonization papers were planned among partners. The six manuscripts are on landscape processes, livestock, mechanization, nutrition, agricultural scaling, and water management. With the exception of the landscape and nutrition papers which are close to journal submission stages, the other four papers have also gained momentum and the teams are holding periodic meetings to reach a consensus on the overall direction and which peer-reviewed journals to submit the manuscripts to.
4. **Implications of COVID on partner activities:** We present a summary of how Africa RISING work in West Africa has been affected by the COVID-19 crisis. The cropping season is normally from July through November of each year. Field activities were successfully concluded in 2019. Ongoing activities were principally around capacity building and conducting surveys and focused group discussions. In relation to the national COVID-19 guidelines in the two West Africa Project countries (Ghana and Mali), no public gatherings are allowed although movements are allowed with some restrictions in some areas. Most national research institutions are slowly partially re-opening pending directives from higher government authorities. Further updates can be accessed here: http://africa-rising-wiki.net/images/9/9a/COVID_Impact_on_WA_AR_Workplans.docx
5. **Implemented research by country**

   <u>Ghana</u>

   i. Activities in Ghana are building on previous efforts reported in the past reporting cycle such as the agronomic trials on cowpea living mulch in combination with environmental measurements such as soil and water measurement and fertilizer trials of blends and compound types, forage-legume intercrops, as well as livestock activities. These sub-activities are elaborated upon further in this report and we share current results emerging from these studies.

ii. A region-wide survey on risks and resilience of AR communities in the context of the agronomic technologies was conducted in November 2019 and covered 545 respondents. This work on resilience of farming systems in Northern Ghana was concluded and a publication has been drafted.
iii. Data collection on the use of improved feed troughs during the dry season progressed well.
iv. Individual and group trainings were an integral part of project activities during the reporting period. Farmers were trained in maize shelling use as well as practicing good agronomic management.

<u>Mali</u>

i. Three manuscripts were published in peer-reviewed journals from data that were collected in previous years. An update is provided in the selected reports and publications section.
ii. Different fertilizer sources which combined both organic (cow and poultry manure) and inorganic fertilizer application on three sorghum varieties (Soumba, Fadda, and Tieble) were evaluated with the target of increasing productivity (grain and stover yield). Over the three cropping seasons (2017 to 2019), results revealed that both grain and stover yields varied significantly among varieties, and different fertilizer treatments and sources applied across three agroecological sites (Bamako, Bougouni, and Koutiala). Grain yield from different fertilizer treatments and sources increased by 8 to 40% in Koutiala, 11 to 53% in Bougouni, and 44 to 110% in Bamako, with average stover yields > 5000 kg/ha compared to the control across the locations. Fadda recorded the highest grain yield over Soumba and Tieble. Mean grain yield produced by Fadda was 23% and 42% higher than those of Soumba and Tieble varieties.
iii. Four high-yielding, dual-purpose sorghum hybrids (ICSX 17651145:H, ICSX 1765232:H, ICSX 1765505:H, and ICSX1765690:H) were evaluated against the previously released hybrid Fadda and a local variety. Agronomic data together with farmers' preferences were recorded to identify the best hybrid that combines the advantage of grain yield, stover yield, and taste quality. All the four new hybrids showed grain yield advantage compared to Fadda (3.2 MT/ha) and this yield gain varied from 6% (ICSX 17651145:H) to 16% (ICSX 1765232:H). All the hybrids were equally or better preferred by male and female farmers than Fadda.
iv. Model parameterization was conducted using DSSAT and APSIM models for dual-purpose sorghum varieties (Soubatimi and Peke) using three sowing dates and different rates of fertilizer. The experiment was conducted on-station at Samanko research station under a controlled environment. The modelling exercise will be repeated for the coming agronomic season (2020) to determine the performance region of the improved varieties of Soubatimi and Peke for sites outside Africa RISING intervention villages. The data previously collected (2015 to 2018) in the two technology parks and in farmers' fields will be used to validate the two models after two years of on-station experimentation.
v. The analysis of farmers' risk perception revealed a large diversity of risks, with hazards related to animal and personal health and climate variability which were of the highest concern. Resource endowment of farms was related to risk perception to a limited extent. Differences within the household were related to age and decision power and not to gender. Farmers with decision power

worried most about risks. Farmers applied a variety of actions to cope with hazards, yet in many cases, farmers lacked a response.

vi. Through the ongoing work of several postgraduate students, data has been collected and analyses are underway that will allow the project to assess the effects of selection index (SI) options and scenarios on a wide range of SI indicators, including risk and economic indicators. The scenario analysis revealed that incremental changes in agricultural practices (e.g., better crop-livestock integration) were insufficient to reduce poverty and achieve food security. A more drastic system transformation is needed such as combining policies supporting conducive marketing conditions, off-farm employment and reduced birth rates, with incentives for increased but sustainable use of agriculture inputs and mechanization. A manuscript has been submitted for publication for this work.

Introduction

The United States Agency for International Development (USAID) is supporting multi-stakeholder agricultural research projects to sustainably intensify key African farming systems as part of the US government's "Feed the Future" initiative to address global hunger and food security issues in sub-Saharan Africa (SSA). IITA is the lead institute for developing and implementing the Sudan-Guinea savanna zone project of Africa RISING. The project primarily focuses on the maize/rice-legume-vegetable-livestock and sorghum/millet-legume-vegetable-livestock farming systems in the Guinea and Sudan savanna ecological zones of the West African region using northern Ghana and southern Mali, respectively, as representative implementation sites. Thus, technologies and practices developed from Africa RISING research at the project sites in Ghana and Mali to reduce poverty, food insecurity, and environmental degradation can also be used in other countries with similar biophysical and socioeconomic conditions within and outside the West African region—providing international public goods.

Phase 1 (1 October 2012–30 September 2016) of the USAID-funded Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) project in West Africa (WA) was implemented in 25 intervention communities in northern Ghana and nine villages in the Bougouni and Koutiala districts of the Sikasso Region in southern Mali under the title "Sustainable intensification of key farming systems in the Guinea-Sudano-Sahelian Zone of West Africa".

Phase 2 (1 October 2016–30 September 2021) of the WA project was launched in February 2017. Implementation is being guided by achievements and lessons from Phase 1. The activities and sub-activities are mapped under the four outcomes in the Africa RISING West Africa Project Phase 2 log frame. Twenty-two sub-activities are being implemented in the Ghana workplan, while 16 are being implemented in Mali. The distribution of the sub-activities per outcome is as presented in Table 1.

Table 1. Tabular logframe summary of ongoing activities.

Country	**Outcome 1**	**Outcome 2**	**Outcome 3**	**Outcome 4**
Ghana	10	5	2	5
Mali	10	1		5

Linkages between activities, gender mainstreaming, capacity building, and knowledge exchange and dissemination are embedded within all sub-activity plans. Publication of research results and better communication among research teams within and across countries form a major focus.

This report presents progress on implementing activities listed under the various outputs in Appendix 1 for the period 01 October 2019 through 31 March 2020. It builds on the technical report for the periods 01 April 2019 to 30 September 2019. The report is presented as sub-activities following similar numbering in the workplans for both Ghana and Mali with a logical sequence to the West Africa log-frame of outcomes, outputs, and their associated activities.

Implemented work and achievements

Outcome 1: Farmers and farming communities in the project area are practicing more productive, resilient, and profitable and sustainably intensified crop–livestock systems linked to markets

Output 1.1: *Research products for more productive, intensive, diverse, profitable, and resilient crop (cereals, legumes, and vegetables); livestock (sheep, goats, cattle, poultry, and pigs), and integrated crop–livestock farming systems are identified and disseminated to farmers through development partners*

Activity 1.1.1: *Test and disseminate a combination of climate-smart crop varieties and agronomic practices to increase and sustain food and feed production*

Sub-activity GH1111-19: Cowpea living mulch effect on weed control, soil properties, and maize yield (Lead Institution: IITA)

This work was conducted in 12 intervention communities across the three northern regions. The experiments were conducted in community-based technology parks (4 parks per region making a total of 12 technology parks) which are researcher/farmer managed trials and 52 upscaling fields which are also farmer managed trials each on a 0.4 ha of land per farmer. The experiments in technology parks were a 4 × 3 factorial treatment combination in a randomized complete block design with four communities per region as replicates. The upscaling trial was a randomized complete block design with four cowpea living mulch as treatments and 52 farmers as replicates. Community field days (08–18/10/2019) were organized for both beneficiary (registered Africa RISING farmers) and non-beneficiary (non-registered Africa RISING farmers) farmers across all three regions (N = 1131) to assess the performance of the intervention. During the field days, focus group discussions were organized for the upscaling farmers to assess the sustainability of cowpea living mulch as a technology using the Sustainable Intensification Assessment Framework[1].

Results from the technology parks indicate that planting cowpea living mulch in maize cropping systems reduced overall mean maize grain yield by about –46% ($P < 0.01$), weed biomass reduced by about 100%, and calorie reduction by –18% but increased protein production by 75% compared with the control ($P < 0.01$) (Table 2). The upscaling trial results also show that in the Northern Region, cowpea living mulch reduced ($P < 0.01$) maize grain yield by –57% and calorie by –52% from both genders of the managed fields. In the Upper East Region, cowpea living mulch significantly increased maize grain yield by +23% and calorie by +67% from the male farmer managed fields. Similarly, cowpea living mulch increased ($P < 0.01$) the protein production in both gender-managed trials in the Northern by +46% and the Upper East regions by about 100%, and in the Upper West Region (about 300%). A total of 696 farmers participated in the farmer preference evaluations for cowpea living mulch and maize maturity-type. The majority of the beneficiary and non-beneficiary farmers preferred the cowpea living mulch technology over the control in the Northern and Upper East Regions whilst the reverse was the

[1] Musumba, M., P. Grabowski, C. Palm, and S. Snapp. 2017. Guide for the sustainable intensification assessment framework. https://cgspace.cgiar.org/bitstream/handle/10568/90523/ftf_guide_oct2017.pdf?sequence=1

case in the Upper West Region (Fig. 1). The majority of the farmers (> 90%) (beneficiary and non-beneficiary) preferred the medium maize maturity type (Obatanpa) in the Northern Region while those in Upper East and West regions preferred the extra-early maize maturity-type (Abontem). Farmer perception on the sustainable intensification rating of the cowpea living mulch showed that both male and female farmers across the three northern regions on average rated the cowpea living mulch as performing very well in the environment and human domains with a score of 90–100% *(Graphical results not presented herein but available on request)*, followed by the productivity and economic domains with a score of 80–90%. However, both male and female farmers especially in the Upper West Region rated the cowpea living mulch technology below average (< 50%) in terms of the social domain.

Analysis, interpretation, and discussion of achievements

The agronomic data were analyzed using general linear model (GLM) of Statistical Analysis Software (SAS) version 9.4. The reduction and increase in maize grain yield from the cowpea living mulch could be due to competition for resources such as nutrients, water, and solar radiation between maize and cowpea crops. In consonance with the results, several studies have reported either a reduction in the grain yield of the main crop[2,3] or an increase in the grain yield of the main crop under living mulch conditions[4,5]. The reduction of weed biomass in the cowpea living mulch system could be attributed to the reduction in the niche available to the weeds by the cowpea canopy. Several studies have reported on the significant effect of mulching on weed control[6,7]. The increase in protein production from the cowpea living mulch is due to the contribution of protein from the cowpea plants. The farmers attributed their preference for the cowpea living mulch to its ability to conserve soil moisture during the dry spell, improve household food diversity, and smother weeds and reduce weeding frequency especially at the peak of the labor demand for agricultural activities. Similarly, the farmers also attributed their preference for the extra-early maize maturity-type to the uncertainty in distribution pattern of the rainfall and the short cropping season.

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[2] Zemenchik, R.A., K.A. Albrecht, C.M. Boerboom, and J.G. Lauer. 2000. Corn production with Kura clover as a living mulch. Agronomy Journal 92: 698–705.

[3] Kamara et al. 2017

[4] Hartwig, N.L. and H.U. Ammon. 2002. Cover crops and living mulches. Weed Science 50: 688–699.

[5] Trail, P., O. Abaye, W.E. Thomason, T.L. Thompson, F. Gueye, I. Diedhiou, M.B. Diatta, and A. Faye, A., 2016. Evaluating intercropping (living cover) and mulching (desiccated cover) practices for increasing millet yields in Senegal. Agronomy Journal 108: 1742–1752.

[6] Hartwig, N.L. and H.U. Ammon. 2002. Cover crops and living mulches. Weed Science 50: 688–699.

[7] Banik P., A. Midya, B.K. Sarkar, and S.S. Ghose. 2006. Wheat and chickpea intercropping systems in an additive series of experiment: advantages and weed smothering. European Journal of Agronomy 24: 325–332.

Table 2. Effect of cowpea living mulch and maize maturity-type on grain yield, weed biomass, calorie, and protein in Northern Ghana (Technology Parks*).

	Grain yield (kg/ha)		Weed biomass	Calorie (kcal/ha × 10^3)	Protein (g/ha × 10^3)
	Maize	Cowpea	(g/m^2)		
Northern Region					
Cowpea living mulch					
No mulch (Control)	1913.3	-	205.2	6983.7	200.6
Cowpea mulch same day with maize	1428.9	590.9	73.8	5414.0	339.0
Cowpea mulch 1 week after maize	1610.0	558.3	77.6	6064.1	308.9
Cowpea mulch 2 weeks after maize	1770.0	598.8	70.2	6661.7	346.8
Standard error of mean	194.34	99.50	4.55	717.63	29.40
P-value	0.3428	0.9547	<.0001	0.4370	0.0044
Maize maturity type					
Abontem (Extra-early)	1330.8	631.0	107.8	5016.6	276.3
Omankwa (Early)	1825.8	489.8	105.3	6787.7	252.5
Obatanpa (Medium)	1885.0	627.2	107.0	7038.3	367.7
Standard error of mean	168.30	99.50	3.94	621.49	25.46
P-value	0.0507	0.529	0.8956	0.0562	0.0075
Upper East Region					
Cowpea living mulch					
No mulch (Control)	1816.9	-	172.2	6631.6	171.2
Cowpea mulch same day with maize	836.8	384.0	67.9	4344.5	169.1
Cowpea mulch 1 week after maize	1355.8	213.9	79.9	5667.3	178.0
Cowpea mulch 2 weeks after maize	1393.4	137.9	93.4	5549.4	163.7
Standard error of mean	92.10	15.75	10.54	340.52	9.34
P-value	< 0.0001	< 0.0001	< 0.0001	0.0005	0.7529
Maize maturity type					
Abontem (Extra-early)	1321.1	245.2	90.6	5439.9	167.7
Omankwa (Early)	1428.2	252.2	117.2	5848.4	179.0
Obatanpa (Medium)	1302.9	238.3	102.3	5356.2	164.8
Standard error of mean	79.76	15.75	9.12	294.90	8.09
P-value	0.4942	0.8247	0.1350	0.459	0.4304
Upper West Region					
Cowpea living mulch					
No mulch (Control)	2440.0	-	67.4	8906.0	229.8
Cowpea mulch same day with maize	1236.7	670.0	45.4	6765.0	646.0
Cowpea mulch 1 week after maize	1697.8	482.2	50.6	7817.2	541.0

	Grain yield (kg/ha)		Weed biomass (g/m^2)	Calorie (kcal/ha × 10^3)	Protein (g/ha × 10^3)
	Maize	**Cowpea**			
Cowpea mulch 2 weeks after maize	2250.0	320.0	47.8	9287.7	464.8
Standard error of mean	184.78	36.51	2.77	645.91	25.68
P-value	0.0002	< 0.0001	< 0.0001	0.0397	< 0.0001
Maize maturity type					
Abontem (Extra-early)	2088.3	478.9	50.5	8829.2	50.5
Omankwa (Early)	1720.8	498.9	51.3	7538.2	51.3
Obatanpa (Medium)	1909.2	494.4	56.6	8214.5	56.6
Standard error of mean	160.02	36.51	2.40	559.38	2.40
P-value	0.2812	0.9209	0.1623	0.2776	0.7642

In relation to this sub-activity, gender data collected in 2019 have been processed and are ready for the development of a publication. A short literature review has been drafted to support the write-up. The team plans to contribute to an article that presents Sustainable Intensification Assessment Framework (SIAF) results from bio-physical, economic, and social science perspectives. In February 2020, social science results were used to validate a causal loop diagram on cowpea living mulch. The causal loop diagram was drafted by economists and biophysicists in late 2019. Further details on this are provided in Sub-activity GH3211-19.

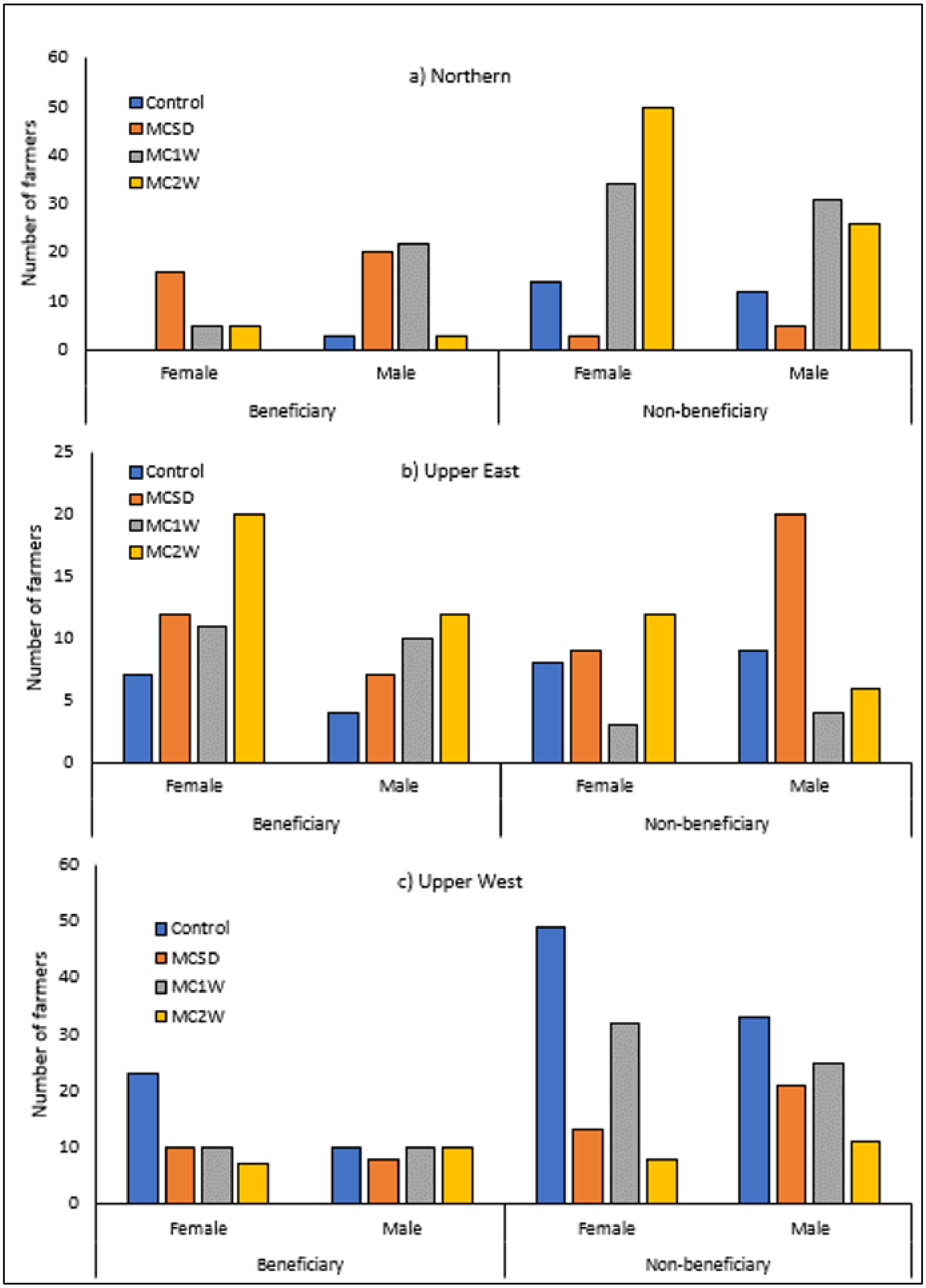


Figure 1. Farmers' preference for cowpea living mulch in maize cropping system in northern Ghana. MCSD = Cowpea living mulch same day with maize, MC1W = Cowpea living mulch 1 week after maize, MC2W = Cowpea living mulch 2 weeks after maize. Beneficiary farmers = Africa RISING farmers who received training, and non-beneficiary farmers = non-Africa RISING farmers with no training.

Sub-activity MA1111-19: Evaluating crop simulation models using different fertility sources and climate model outputs to improve the productivity of sorghum (Lead institution: ICRISAT)

This sub-activity was conducted in Mali in 2018. Different fertilizer sources which combined both organic (cow and poultry manure) and inorganic fertilizer application on three sorghum varieties (Soumba, Fadda, and Tieble) were evaluated with the target of increasing productivity (grain and stover yield). Over the three cropping seasons (2017 to 2019), results revealed that both grain and stover yields varied significantly among varieties, fertilizer treatments, and sources applied across three agro-ecological sites (Bamako, Bougouni, and Koutiala). Grain yield from different fertilizer treatments and sources increased by 8 to 40% in Koutiala, 11 to 53% in Bougouni, and 44 to 110% in Bamako, respectively with average stover yields > 5000 kg/ha compared to the control across the locations. Fadda recorded the highest grain yield over Soumba and Tieble. Mean grain yield produced by Fadda was 23% and 42% higher than that of Soumba and Tieble varieties.

Analysis, interpretation, and discussion of achievements

Agronomic experimental design: The experimental design was a split plot arrangement with four replications. The treatments included three sorghum varieties (Soumba, Fadda, and Tieble [CSM335]) as main plot and nine different fertilizer treatments (inorganic fertilizer [DAP 18:46:00], cow manure, poultry manure, and the combination of cow manure) and a control as sub-plot. The gross size of each plot was 15 m^2 which consisted of four ridges spaced at 75 cm apart and sowing was done at 30 cm between plants, giving a total plant population of 44 440 hills per hectare. The fertilizer treatments were as follows: T1 = Control; T2 = Cow manure (50 g/hill) + Poultry manure (50 g/hill); T3 = Cow manure (100 g/hill); T4 = Cow manure (100 g/hill) + Micro-D_DAP (3 g/hill); T5 = Micro-D_DAP (3 g/hill); T6 = DAP 41:46:00; T7 = Poultry manure (150 g/hill); T8 = Poultry manure (100 g/hill); T9 = Poultry manure (50 g/hill); T10 = Poultry manure (100 g/hill) + micro-D_DAP (3 g).

Table 3. Interaction effect of year and fertilization sources on grain yield and stover yield in Koutiala, Bougouni, and Bamako, respectively (from 15 m^2 plots with each plot having a total plant population of 44 440 hills per hectare).

Fertilization (F)	Koutiala				Bougouni				Bamako			
	2017	2018	2019	Mean	2017	2018	2019	Mean	2017	2018	2019	Mean
Grain yield (kg/ha)												
T1	1505	2060	1680	1748	1933	1108	1242	1427	1324	640	1491	1152
T2	1862	2770	1978	**2203**	2903	1577	1872	**2117**	1801	2124	2015	1980
T3	1676	2577	1798	**2017**	2074	1596	1578	1999	1838	1500	2170	1836
T4	1793	2474	2047	**2105**	2824	1546	1186	1602	1946	2211	2203	**2120**
T5	1737	2313	1622	1891	2781	1448	1790	**2006**	1881	1746	1854	1827
T6	1778	2734	1886	**2133**	2659	1481	1518	1886	1728	2085	1740	1851
T7	1423	2389	2177	1996	2257	1510	1540	1769	2017	2263	2297	**2192**
T8	1922	2736	1798	**2152**	2888	1628	2022	**2179**	1794	2144	2446	**2128**
T9	1702	2361	1913	1992	2413	1292	1059	1588	1535	1275	2167	1659
T10	2143	3029	2192	**2455**	2864	1904	1800	**2189**	2099	2582	2570	**2417**
SED of Y ($P \leq 0.05$)	58*				66**				77**			
SED of F ($P \leq 0.05$)	130*				109**				170*			
SED of Yx F ($P \leq 0.05$)	197^{ns}				201^{ns}				115*			
CV (%)	19.6				24.5				25.0			
Stover yield (kg/ha)												
T1	13573	10458	7763	10598	13433	7113	5330	8625	5834	6284	7253	6457
T2	14122	12317	8736	11725	12708	7753	6532	8998	6639	6695	6559	6631
T3	12070	10400	8000	10157	9334	7643	5918	7632	6160	4748	7658	6189
T4	12190	9975	8552	10239	13061	8698	6743	9501	6444	7920	7525	7296
T5	11408	8592	8428	9476	12513	8330	6710	9184	5263	5086	5875	5408
T6	15076	8075	8857	10669	11966	7162	6610	8579	4682	5538	5906	5375
T7	10177	11217	9291	10228	10158	7041	6770	7990	6158	6819	6773	6583
T8	12324	10508	8988	10607	12994	8787	7293	9691	6097	8178	7972	7416
T9	11779	11800	8659	10746	10856	5532	4217	6868	5947	5272	6825	6015
T10	14089	11658	8863	11537	12888	7608	7067	9188	6985	6816	7797	7199
SED of Y ($P \leq 0.05$)	415**				331**				251**			

Fertilization (F)	Koutiala				Bougouni				Bamako			
	2017	**2018**	**2019**	**Mean**	**2017**	**2018**	**2019**	**Mean**	**2017**	**2018**	**2019**	**Mean**
SED of F ($P \leq 0.05$)	1260^{ns}				663**				550**			
SED of Yx F ($P \leq 0.05$)	1655*				1081^{ns}				849^{ns}			
CV (%)	14.5				16.8				17.8			

NB: T_1 = Control; T_2 = Cow (50 g/hill) + Poultry (50 g/hill); T_3 = Cow manure (100 g/hill); T_4 = Cow manure (100 g/hill) + Micro-D_DAP(3 g/hill); T_5 = Micro-D_DAP (3 g/hill); T_6 = DAP41:46:00; T_7 = Poultry manure (150 g/hill); T_8 = Poultry manure (100 g/hill); T_9 = Poultry manure (50 g/hill); T_{10} = Poultry manure (100 g/hill) + Micro-D_DAP(3 g/hill). SED = Standard error of differences of means.

Table 3 shows the significant effects of year (Y) and fertilization (F) on grain and stover yields across the sites. A significant interaction of year and fertilization (Y × F) was observed in Bamako but not in Koutiala and Bougouni. Both grain and stover yields produced from fertilizer treatments and sources (T2–T10) were significantly higher than that of the control (T1) in all the three locations except for stover yield in Koutiala. T2–T10 showed increased grain yield of 8–40% in Koutiala, 11–53% in Bougouni, and 44–110% in Bamako, respectively, compared to the control (T1). This implies the fertilization strategies have the potential for higher grain and stover yields with average stover yield > 5000 kg/ha across the locations. At mean yield ≥ 2000 kg/ha, fertilization strategies T2, T3, T4, T6, T8, and T10 were found to be higher than those for other treatments in the Koutiala site. In Bougouni, T2, T5, T8, and T10 were higher than those for other treatments while T10 (2189 kg/ha) produced the mean highest value. Also, in Bamako, fertilization sources T4, T7, T8, and T10, respectively, produced higher yields than others.

Figure 2 shows the monthly distribution of rainfall and the total number of rainy days (NRD) recorded during the growing season (May to October) across the sites. Significant year-to-year rainfall variability was observed in Koutiala and Bougouni indicating low to high rainfall year, but no significant variability was observed in Bamako. Similarly, significant variability was observed for monthly rainfall patterns with the NRD ranged from 32 to 72 days across the sites. The cumulative rainfall received in July and August constituted about 44 to 72% (in Bamako and Bougouni) and 52 to 65% (in Koutiala) of total seasonal rainfall received.

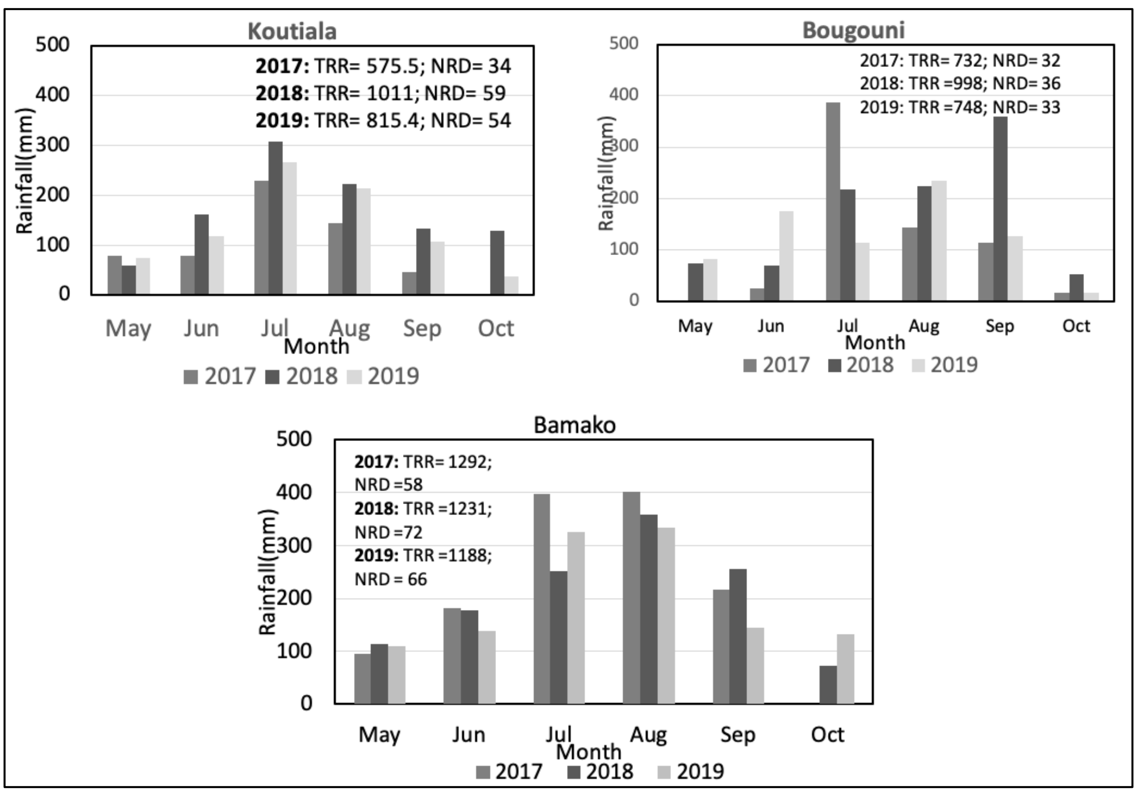


Figure 2. Monthly rainfall distribution, total rainfall (TRR), and number of rainy days (NRD) at the three stations between 2017 and 2019.

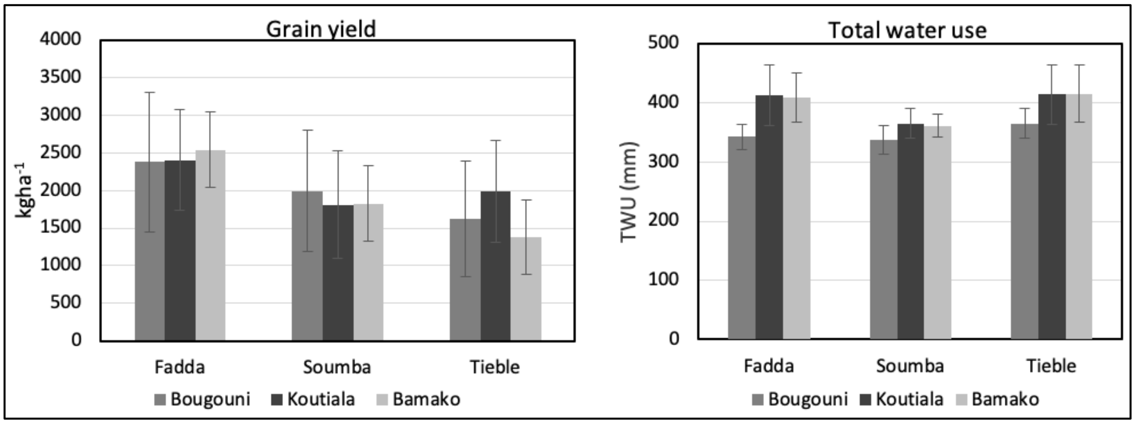
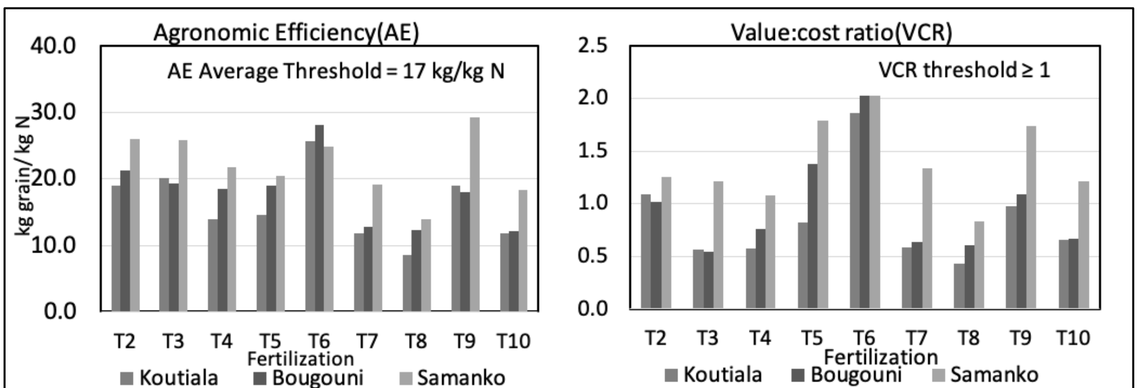


Figure 3. Effects of fertilization strategies and location on sorghum varieties relative to grain yield and total water use (TWU) over cropping seasons (2017–2019).

Figure 3 reveals significant ($p < 0.001$) interaction of location, fertilization, and variety (L × F × V) on both grain yield (GY) and total water use (TWU). Fadda produced the highest grain (2381–2543 kg/ha) across the sites followed by Soumba (1813–1994 kg/ha), and Tieble (1381–1990 kg/ha), respectively. Fadda and Soumba varieties were confirmed as dual-purpose sorghum and could be adapted to the three sites when good agricultural practices are maintained while Tieble could only be adapted to Koutiala considering the low average yield observed in Bamako and Bougouni. In addition, based on the total rainfall received during cropping seasons as the only source of water for the growth of the sorghum cultivars tested, the estimated TWU by individual variety fell lower (337–415 mm) compared to the required range (450–650 mm) for sorghum under semi-arid conditions as reported by Jewitt et al. (2009)[8]. This implies that water may not be a constraint for sorghum production across the three sites except in an extremely dry rainfall year.



[T_2 = Cow (50 g/hill) + Poultry (50 g/hill); T_3 = Cow manure (100 g/hill); T_4 = Cow manure (100 g/hill) + Micro-D_DAP (3 g/hill); T_5 = Micro-D_DAP (3 g/hill); T_6 = DAP41:46:00; T_7 = Poultry manure (150 g/hill); T_8-Poultry manure (100 g/hill); T_9 = Poultry manure (50 g/hill); T_{10}- Poultry manure (100g/hill)+ Micro-D_DAP(3g/hill)].

Figure 4. Performance of different fertilization sources on the agronomic efficiency (AE) and value: cost ratio (VCR) in Koutiala, Bougouni, and Samanko (Bamako).

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[8] Jewitt G.W.P., H.W. Wen., R.P., Kunz, R.P., and V. Rooyen. (2009) Scoping study on water use of crops/trees for biofuels in South Africa. WRC Report No. 1772/1/09. Water Research Commission, Pretoria.

The estimated agronomic efficiency (AE) and value: cost ratio (VCR) were significant and differ among the fertilization sources (T2–T10) and sorghum varieties tested (Figs 4 and 5). As shown in Figure 4, only a few fertilization sources fall within the average threshold AE of 17 kg grain/kg N and VCR of ≥ 1. Following the threshold, the fertilization management, and sources for efficient use of nitrogen (N) inputs indicated T2, T3, T6, and T9, respectively, in Koutiala and T2–T6, and T9 in Bougouni. This was true for all the fertilization management and sources treatments except T8 in Bamako. Similarly, for VCR, only T2, T6, and T9 were suitable in Koutiala; T2, T5, T6, and T9 in Bougouni; and all the fertilization management and sources except T8 in Bamako. Results imply that at VCR ≥ 1 farmers would break even and make profit if they adopted the new practices or technologies. As depicted in Figure 5, the estimated AE and VCR by Fadda variety were significant and higher compared to the values for Soumba and Tieble varieties across locations. However, the farmers may not break even (VCR < 1) using Soumba and Tieble varieties in Koutiala.

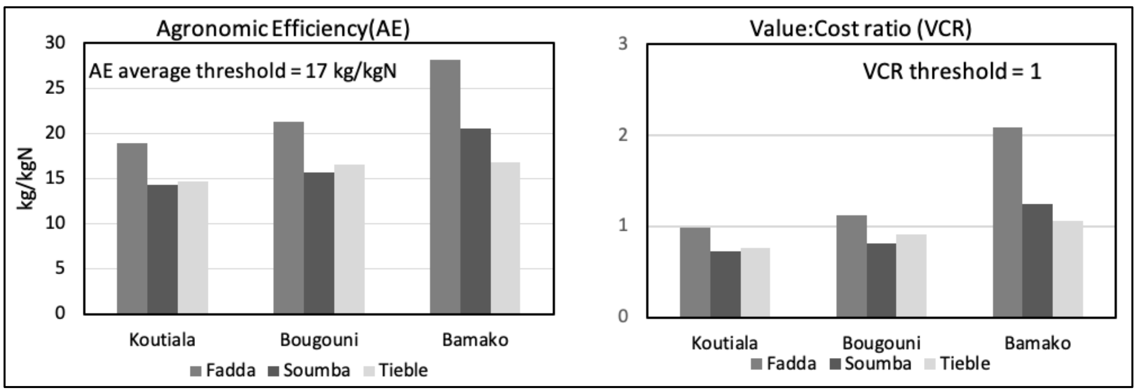

Figure 5. Performance of sorghum variety on the estimated agronomic efficiency (AE) and value:cost ratio (VCR) in Koutiala, Bougouni, and Samanko, respectively.

Conclusion and recommendation for farmers: Throughout the cropping seasons (2017–2019), the study demonstrated a benefit of the use of organic manure from both ruminants and non-ruminants as an alternate or complementary organic fertilizer in a micro-dosing technology to boost sorghum yield with significant high-yielding potential, but not all resulted in economic gain. Based on the results obtained over three years, the study suggests the following:

- The use of the three varieties (Fadda, Soumba, and Tieble) along with the multiple-choice of treatment—T2 (Cow [50 g/hill] + Poultry [50 g/hill]), T5 (DAP Micro-D [3 g/hill]), and T9 (Poultry manure [50 g/hill])—for farmers in Koutiala for both high productivity and profitability.
- Use of only Fadda and Soumba varieties along with multiple choices of fertilization strategies—T2 (Cow [50 g/hill]+Poultry [50 g/hill]), T4 (Cow manure [100 g/hill] + Micro-DAP[3 g/hill]), T5 (DAP Micro-D [3 g/hill]), T6 (DAP41:46:00), and T9 (Poultry manure [50 g/hill]), respectively, for maximum profitability in Bougouni and Bamako regions.

Sub-activity GH1112-19: Optimizing on-farm nitrogen (N) fertilizer use efficiency under rainfed conditions and leaf stripping for livestock feeding in maize-based cropping system (Lead Institution: IITA)

This sub-activity was conducted in 12 community-based technology parks and 207 upscaling fields. The technology park trial was a 4 × 3 factorial treatment combination with a strip plot design with four communities per region as replicates while that of the upscaling trial was a 2 × 3 factorial treatment combination in a randomized complete block design with 207 farmers as replicates. The technology park results showed that application of compound fertilizer to maize increased ($P < 0.01$) grain yield (+38%) and calorie (+38%) more than that of the new blend fertilizer (Table 4). Application of basal fertilizer at either planting or planting + two weeks after planting had higher ($P < 0.05$) maize grain yield (+50%), NUE (+63%), and calorie (+50%) than that of the conventional practice (Table 4). Similarly, the results of upscaling fields also showed that application of basal fertilizer at either planting or planting + two weeks after planting increased ($P<0.01$) maize grain yield (+34) and calorie (+34) than that of the conventional practice in both gender-managed fields. A total of 676 farmers participated in the evaluation of farmer preference for fertilizer type and time of application of basal fertilizer during the community field days. The majority (2%) of the farmers (beneficiary and non-beneficiary) preferred the performance of maize under the new blend fertilizer than the performance under the compound fertilizer. In terms of the time of application of basal fertilizer, the majority of the beneficiary and non-beneficiary farmers (> 90%) preferred the growth performance of maize under the application of basal fertilizer at planting than the performance under conventional practice. During the reporting period, there were 12 community field days which offered farmers and high school students from five senior high schools short-term capacity building in the Northern, Upper East, and Upper West regions (1131 participants between 8 and 18 October 2019). Of the 1131 participants, 632 were males and 499 were females.

Table 4. Maize grain yield, nitrogen use efficiency (NUE), and calorie production as affected by fertilizer type and time of application of basal fertilizer in Northern Ghana (technology park).

	Grain yield (kg/ha)	NUE (kg/kg N)	Calorie (kcal/ha x10^3)
Northern Region			
Fertilizer type			
[1]New blend (NB)	2033.3	18.1	7421.7
[2]Compound (CP)	1835.6	11.4	6699.8
NB + Organic fertilizer (2.5 MT/ha)	1816.7	15.7	6630.8
CP + Organic fertilizer (2.5 MT/ha)	1944.4	12.3	7097.2
Standard error of mean	262.19	2.74	957.00
Time of fertilizer application			
Planting	2265.8	17.8	8270.3
2 weeks after planting (conventional)	1369.2	9.3	4997.5
Planting + 2 weeks after planting	2087.5	16.0	7619.4
Standard error of mean	135.68	1.26	495.25
Contrast probability of P-value			
Blend vs Compound	0.7619	0.0002	0.7619
Inorganic vs (Inorganic + Organic)	0.6414	0.4795	0.6414
Conventional vs Others	< 0.0001	< 0.0001	< 0.0001
Planting vs (Planting + 2 weeks after planting)	0.2168	0.1767	0.2168
Upper East Region			
Fertilizer type			
New blend (NB)	1678.0	15.8	6124.7
Compound (CP)	2047.8	19.9	7474.4
NB + Organic fertilizer (2.5 MT/ha)	1700.7	11.5	6207.4
CP + Organic fertilizer (2.5 MT/ha)	2002.3	13.9	7308.5
Standard error of mean	159.21	1.32	581.12
Time of fertilizer application			
Planting	2117.6	17.7	7729.2
2 weeks after planting (Conventional)	1652.2	13.4	6030.4
Planting + 2 weeks after planting	1801.8	14.7	6576.7

	Grain yield (kg/ha)	NUE (kg/kg N)	Calorie (kcal/ha x10^3)
Standard error of mean	80.15	0.65	292.56
Contrast probability of P-value			
Blend vs Compound	0.0030	0.0041	0.0030
Inorganic vs (Inorganic + Organic)	0.9087	< 0.0001	0.9087
Conventional vs Others	0.0083	0.014	0.0083
Planting vs (Planting + 2 weeks after planting)	0.0169	0.0231	0.0169
Upper West Region			
Fertilizer type			
New blend (NB)	2720.0	28.3	9928.0
Compound (CP)	4010.0	30.7	14636.5
NB + Organic fertilizer (2.5 MT/ha)	2945.6	30.8	10751.3
CP + Organic fertilizer (2.5 MT/ha)	4365.6	33.5	15934.3
Standard error of mean	199.96	2.08	729.85
Time of fertilizer application			
Planting	4296.7	39.2	15682.8
2 weeks after planting (conventional)	2435.0	19.9	8887.8
Planting + 2 weeks after planting	3799.2	33.4	13867.0
Standard error of mean	320.04	3.16	1168.14
Contrast probability of P-value			
Blend vs Compound	0.0002	0.3889	0.0002
Inorganic vs (Inorganic + Organic)	0.3421	0.3693	0.3421
Conventional vs Others	< 0.0001	< 0.0001	< 0.0001
Planting vs (Planting + 2 weeks after planting)	0.1893	0.1164	0.1893

[1]15-20-20 kg/ha NPK + S + MgO + Zn and [2]23-10-5 NPK + S + MgO + Zn

Gender evaluation of leaf stripping

In March 2020, a follow-up study on the sustainability of the technology was conducted. The aim of this study was to assess reasons for farmers continued or discontinued use of the technology upon completion of biophysical experimentation. The study added nine focus group discussions (3 with women, 6 with men) and five key informant interviews to the main corpus of data collected in early 2019. A publication based on the overall results is in development. The writing team comprises social scientists from IITA and the University of Development Studies, UDS (Tamale, Ghana) as well as an IITA biophysical scientist who is the Principal Investigator of the study.

Gas chamber measurements

An improvised static flow chamber system was used to measure fluxes of ammonia-nitrogen (NH_3-N), where NH_3N = (14/17) (NH_3) from soil surfaces. The experimental sites were Cheyohi, Tingoli in the Tolon district and Savelugu and Doku in the Savelugu districts, all in the Northern Region of Ghana. The measurements were taken during the 2019 growing season in the Guinea Savanna agroecological zone of Ghana, to assess the rate and source of NH_3 in newly introduced fertilizer blends as well as existing compound fertilizers. Plots treated with organic matter together with newly formulated fertilizers were also sampled. In the static chamber method, 10% boric acid with bromocrystol green and methyl red orange indicators at neutral pH was placed inside the chamber used to trap NH_3 emissions from the soil. Soil temperature, soil pH, soil N, and N from added fertilizers were monitored throughout the experimental period. Soil surface temperature did not significantly affect NH_3 emissions. However, the majority of the NH_3 emissions occurred when surface temperature was between 34 and 36 ^oC (Fig. 6). In all applications the new fertilizer blends exhibited low NH_3 emissions.

Where organic matter was applied, NH_3 emissions lasted for a few days after application and following rainfall. Soil pH remained relatively constant throughout the research periods and therefore did not serve as a useful predictor of NH_3 flux. A rainy event followed by a dry period produced a characteristic increase in ammonia emissions. Mixed NH_3 emissions were observed during measurements as a result of the soil moisture availability (Fig. 6). Emission peaks were observed a few days after application especially with the inorganic fertilizers. The new fertilizer blends exhibited lower NH_3 fluxes compared to the compound fertilizers. A maximum of 0.5 ug $NH_3/m^2/S$ was observed from the new fertilizer blends whereas 1.0 ug $NH_3/m^2/S$ was found in the compound fertilizers. The addition of organic fertilizers to the new blends increased the fluxes of the latter although this was not significant. The application of organic matter at 5 MT/ha with the inorganic compound fertilizers produced a 1.4 ug $NH_3/m^2/S$ which was second highest to the application of inorganic new blend and compound fertilizers at five weeks after planting (2.0 ug $NH_3/m/S$) at peak. In most cases, the new blend inorganic fertilizers emitted low NH_3 that could not be deemed as a significant loss of N which could affect crop N availability.

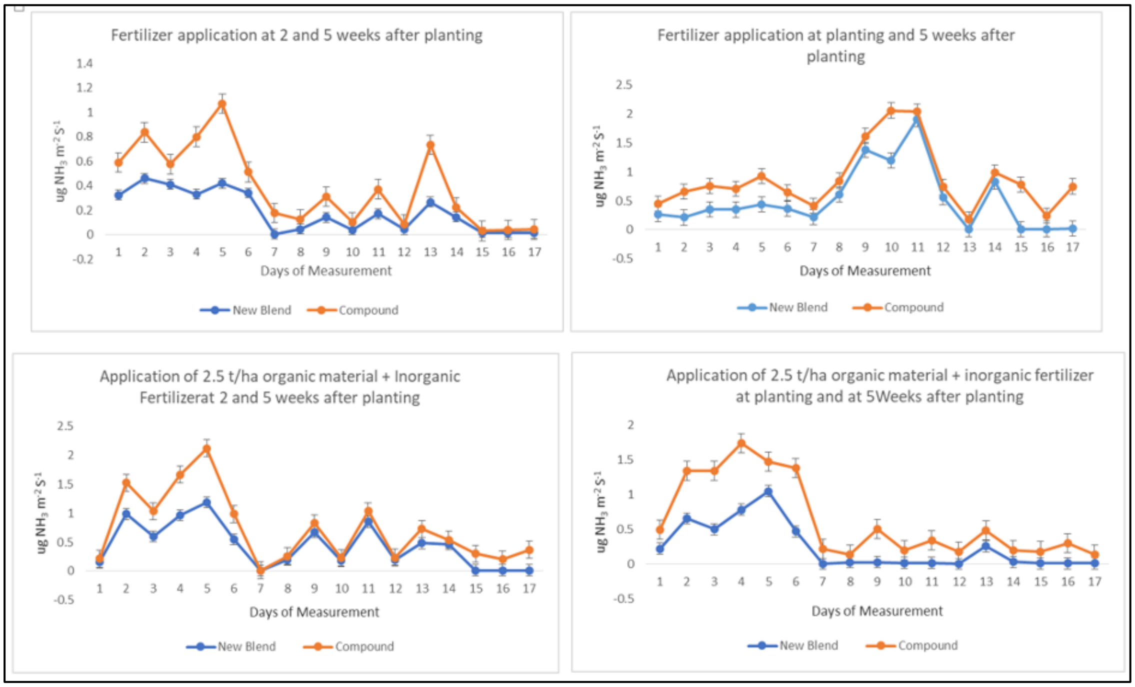

Figure 6. Variation of gas emissions with different soil amendments over time.

The application of well decomposed organic material is essential to reduce NH3 losses and is highly recommended by the study. The team has provided a brief synthesis of this sub-activity, however further graphical and tabular details of these findings are presented in the Technical Report.

Sub-activity MA1112-19: Understanding soil fertility management in cereal cropping systems in southern Mali (Lead institution: ICRISAT)

This sub-activity commenced in 2018 with the mapping of nutrient flows and balances and composting for soil fertility characterization.

Analysis, interpretation and discussion of achievements

The availability of manure stocks across the year depends on farm size and the year. In July 2018 we found little organic manure in the stock with no significant differences between farm type but this has gradually increased to reach the maximum in March to April 2019 with 58 MT for the higher resource endowed (HRE) farmers which was significantly larger ($P < 0.001$) than 35 and 14 MTobtained, respectively, with middle resource endowed farmers (MRE) and low resource endowed farmers (LRE).

The mean quantities of available manure varied from one village to another. In Zanzoni and N'Golonianasso mean manure quantity was 44 and 38 MT per farm, respectively, which was significantly higher than the 29 MT recorded in Sirakele village. Highest stocks were obtained with farmyard manure and compost manure, respectively. HRE and MRE farmers respectively accumulated mean quantity varying from 27 to 22 MT for farmyard manure and from 19 to 8 MT for compost manure. LRE farm types recorded 12 MT of farmyard manure and other sources such as compost or cattle manure were less than one tonne. The amount of manure stored from small ruminants was low compared to that of cattle or compost manure.

Mean planting density was 86 776 and this did not significantly change across treatments while for sorghum biomass and grain yield there were statistically significant differences between treatments. For biomass from whatever compost type, the yield obtained with a dose of 2.5 MT/ha was significantly larger than that obtained with the control treatment. However, with compost type 1 or 2, biomass yield obtained with 5 MT/ha of compost application was similar to that of 2.5 MT/ha of compost application. For sorghum, best grain yield was obtained with 2.5 MT/ha application and whatever compost type was used, it was significantly larger than that of the control and DAP as well.

For grain, yields obtained with 3N, 7N, 10N, and 15N were significantly higher than those obtained with control (0N) as well as with DAP application. However, among corralling treatments (3N, 7N, 10N, and 15N) yields were similar regardless of the duration of corralling. In this case, corralling with 3N remains a short-term potential alternative because in addition to improving yield, it saves time for covering more land. The next round of surveys on nutrient flow will be conducted from March to May 2020 and laboratory results of biomass analysis will be used to model nutrient dynamics per farm type. Experiments on composting and corralling systems will be repeated during the next agricultural period (2020). The team has provided a brief synthesis of this sub-activity; further graphical and tabular details of these findings are presented in the Technical Report.

Sub-activity GH1113-19: Assessing the potential for a combination of local Napier grass fodder species and pigeon peas for improved soil health and ruminant productivity in the guinea savanna zone (Lead Institution: UDS-Faculty of Agriculture)

This study was carried out in the IITA Africa RISING Technology Park in Duko in the Savelugu Nanton District of Ghana between August 2019 and April 2020. A total of nine smallholder crop/livestock farmers comprising six males and three females were involved in this sub-activity. The objective of this study is to assess the fodder yield and quality and to assess the impact of intercropping Napier grass with pigeon pea on grain yield. About one-acre field was ploughed with a tractor and subdivided into three subplots with 12 sub-subplots. The subplots represented the blocks while the sub-subplots (7 m ×4.5 m) represented the replications within a block. The treatments, sole Napier grass, sole pigeon pea, and intercrop of Napier grass and pigeon pea, were arranged in a randomized complete block design (RCBD).

Weekly number of branches or tiller number and plant height were recorded for the pigeon pea and Napier grass. The first harvest of Napier grass was carried out in the 8th week after planting by cutting the stems at a stubble height of about 10 cm with a sickle. Subsequent cuts were scheduled for the 3rd week after the first cut; however, this was not possible due to a drought that set in after the first harvest. The pigeon pea was harvested in the 19th week by cutting the stem at a stubble height of about 40 cm.

The fresh weight of the harvest was recorded and about 30% was sampled for dry matter and nutrient analysis. The samples were transported to the Forage Evaluation laboratory of the Faculty of Agriculture of the University for Development Studies, Tamale, Ghana. About 200 g of each sample was placed in a forced air oven at a temperature of 104 °C for 4 h for dry matter determination. The rest of the samples were shade dried for about one week and milled with a hammer mill through a 1 mm sieve screen. Prior to milling, the pigeon pea samples were separated into grains, husk, and fodder (leaves and twigs). The data was analyzed as a one-way ANOVA in RCBD using GenStat 11th edition. The means were separated using Tukeys at 5%.

Number of branches or tiller number was transformed by determining the square root of the raw values before being subjected to ANOVA.

Napier grass has also been reported to control soil erosion within farming systems in Tanzania and Kenya[9]. In addition, the combination of Napier grass and legumes has been reported to increase water stored in the crop root zone[10]. In this study, places with pigeon pea and Napier grass had higher soil moisture storage (25%) than the sole pigeon pea plots. In addition, there was 34% less runoff estimated from the pigeon pea and Napier intercropped plots compared to the sole crop plots. There was no significant difference between the sole pigeon pea and intercrop for number of branches and plant height. The added merit from reduced runoff was not mediated by biomass but by the canopy cover resulting from the intercrop with Napier grass. In addition, there were no significant differences between the treatments relative to the grain, husk, and fodder yields for both pigeon pea and Napier grass.

The grain yield of pigeon pea was 457 kg and 352 kg ($P > 0.05$) for inter cropped and sole pigeon pea, respectively. The fodder yield was 750 kg and 952 kg for intercropped and sole pigeon pea whilst the husk yield was in the range of 151 kg and 171 kg for the intercropped and sole pigeon pea respectively. Both grain and fodder yield under the current study were lower than what has been reported by previous authors with higher levels of fertilizer application.

The biomass yield for the Napier grass was 5944 kg and 4335 kg for intercropped and sole Napier respectively. Despite the lack of a significant difference, the Napier grass intercrop had a higher yield compared to the sole Napier. The fodder yield from the Napier grass was, however, still lower than the yields reported for the same variety in the humid zone[11].

The yield benefit of the intercrop over sole crop is indicated by a Land Equivalent Ratio (LER) greater than 1.0[12]. In the current study, LER was above 1 for both pigeon pea grain and Napier grass fodder whilst the fodder for pigeon pea fell below 1. The relatively lower LER fodder yield recorded for pigeon pea was due to the drought which led to an extensive leaf drop at the time of harvest.

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[11] Ansah, T., E.L.K Osafo, and H.H. Hansen. 2010. Herbage yield and chemical composition of four varieties of Napier (Pennisetum purpureum) grass harvested at three different days after planting. Agriculture and Biology Journal of North America 1(5): 923–929.

[12] Esmaeili A, A. Sadeghpour, S.M.B Hosseini, E. Jahanzad, M.R. Chaichi, and M. Hashemi. 2011. Evaluation of seed yield and competition indices for intercropped barley (Hordeum vulgare) and annual medic (Medicago scutellata). International Journal of Plant Production 5(4): 395–404.

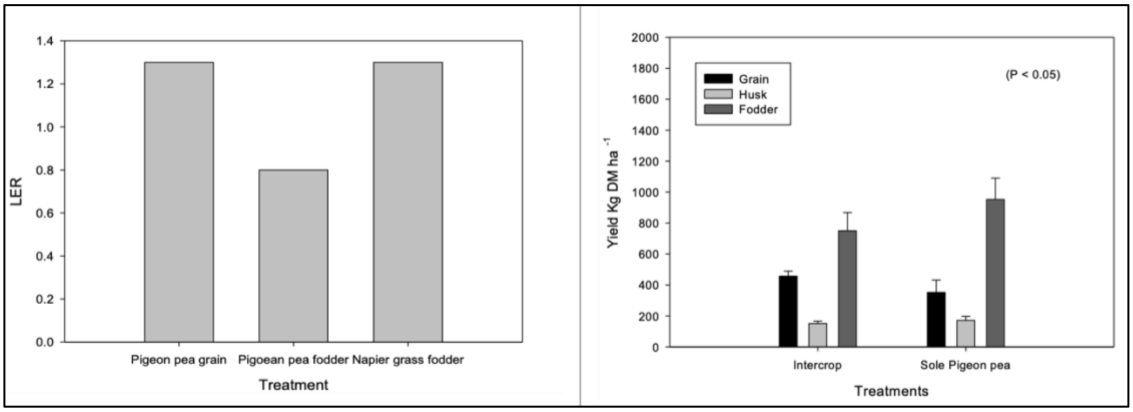


Figure 7. Yield variation among different treatments.

The study revealed that intercropping pigeon pea with Napier did not negatively affect grain and fodder yields. However, crude protein and metabolizable energy in Napier grass intercropped with pigeon pea were enhanced. The total number of fattening sheep growing at 50 g/day that can be supported by the metabolizable energy yield to attain a matured weight of 26 kg ranged from 6 to 37 rams with the highest number of animals estimated in the Napier grass intercrop with pigeon pea. Generally, the grain and fodder yield from the pigeon pea and the fodder yield from Napier grass were lower than yields recommended. The potential metabolizable energy yield from the four treatments may support the growth of 6 to 37 rams with Napier grass intercropped with pigeon pea having the highest potential. In view of the extensive loss of leaves at the time of harvesting the pigeon pea, it is recommended that different degrees of pruning prior to flowering be introduced. However, the effect of the pruning on grain yield should be assessed. Different rates of fertilizer application on Napier grass and pigeon pea is recommended to assess the effect on grain and fodder yields.

Figure 8. Photo grid of sample activities conducted in this quarter: Focus group discussions, forage management, harvests, and feeding of livestock. Photo Credit: Terry Ansah/UDS.

Sub-activity MA1113-18: Evaluating improved dual-purpose sorghum for crop-livestock integration and income generation in Sikasso Region/Mali ((Lead institution: ICRISAT)

Analysis, interpretation, and discussion of achievements

Four agronomic trials were implemented; two in Bougouni (Flola and Madina technology parks; both on 12 July 2019) and two in Koutiala (M'Pessoba and N'Golonianasso technology parks; both on 11 July 11 2019). The locations receive different amounts of annual rainfall varying from 540 mm (at M'Pessoba) to 972 mm (at Flola). The four sorghum hybrids tested in these trials were ICSX 17651145:H, ICSX 1765232:H, ICSX 1765505:H, and ICSX1765690:H. These varieties are short (less than 2 m) and combine the benefit of grain yield as well as fodder yield. In addition to agronomic traits, farmers' preferences (men and women) were recorded for each hybrid through group evaluation and also voting using different colors of cards.

Results showed high variability of grain yield for the new hybrids, 3.5 MT/ha to 4 MT/ha in Bougouni and 3 MT/ha to 3.6 MT/ha in Koutiala compared to Fadda (3.1 MT/ha in Bougouni and

3.2 MT/ha in Koutiala) and to the local varieties (1.6 MT/ha in Bougouni and 2.3 MT/ha in Koutiala). Overall, all the four new hybrids recorded a grain yield advantage over Fadda varying from 6 % (ICSX 17651145:H) to 16 % (ICSX 1765232:H).

Fadda exhibited the highest stover yield both in Bougouni (22 MT/ha) and Koutiala (18 MT/ha) although the difference between genotypes was not statistically significant at 5% (Table 5). Results of hybrid preference indicated that two varieties were highly liked by farmers, these are ICSX 17651145:H (67%) and ICSX 1765505:H (64%) compared to Fadda. ANOVA results (Table 5), showed that all new hybrids, Fadda, and the local variety from Koutiala (Bentoroko) were equally preferred by farmers (56% to 66%) while the local variety from Bougouni was less preferred (28%). Also, all the hybrids had the same maturity (50% flowering between 78 and 84 days) except ICSX 1765690:H which is considered an early maturing hybrid (flowering at 76 days after sowing).

To identify the genotypes combining both grain yield and stover yield, the selection index (SI) was performed as follows: SI = 0.6*Std_GrY + 0.4*Std_FStY; where Std_GrY = standardized value of grain yield; Std_FStY = standardized value of stover yield. Also, 0.6 or 60% and 0.4 or 40% represents the weights assigned to the traits given their socioeconomic importance to farmers. Two hybrids (ICSX 1765232:H and ICSX 1765505:H) recorded higher SI (0.3) compared to Fadda (SI = 0.2) across the locations while the best local variety showed negative SI (-0.3) highlighting that the local varieties do not combine grain and stover yields and quality (Table 5). Important and highly significant differences were observed between genotypes for flowering, grain yield, and farmers' preferences while these differences were not significant for the stover yield (Table 5). The interactions between genotypes and trial locations were highly significant for all the traits; meaning that different genotypes should be proposed to farmers depending on the location.

The activity on sorghum hybrids described earlier followed activities conducted in the years 2017 and 2018 where dual-purpose sorghum open-pollinated varieties (OPVs) were evaluated and the most promising varieties (Soubatimi and Peke) were identified for seed production and commercialization by farmer seed cooperatives. The question now is what are the potential production zones of these varieties while reducing the risks of production?

Thus, an experiment was conducted at Samanko research station using the two dual-purpose sorghum varieties (Peke and Soubatimi), under different types of fertilizer (DAP + urea, cow manure, and zero fertilizer), in three sowing dates. For all sowing dates and both varieties, thinning to desired plant density was done at about 15 days after sowing (DAS) at 1 plant/hill. The planting density was then 4.4 plants/m^2 with 30 cm spacing between hills. Cow manure was applied at a rate of 3 MT/ha; three days before sowing, the DAP at 100 kg/ha 15 days after sowing, and the urea at 50 kg/ha 40 days after sowing. The three replications were distant at 1.5 m while the fertilization levels were separated by 0.75 m. Elementary plots consisted of 8 rows of 5 m long. Prior to sowing, soil samples were taken for laboratory analysis at four different profiles (0–15, 15–30, 30–60, and 60–90 cm). The cow manure was also sampled for the same analyses.

Table 5. Agronomic performance and statistical parameters of the dual-purpose sorghum hybrids.

Genotype	50%FL (day)	Se_50%FL	FStY(t/ha)	Se_FStY	GrY(t/ha)	Se_GrY	PrefG	Se_PrefG	SI	Se-SI
Fadda	82.1ab	1.3	19.9a	1.2	3.2bc	0.2	**63.4b**	5.3	0.2a	0.2
ICSX 17651145:H	81.3ab	1.3	17.6a	1.2	3.4bc	0.2	**66.6b**	5.3	0.1a	0.2
ICSX 1765232:H	78.3ab	1.3	17.3a	1.2	**3.7c**	0.2	57.6ab	5.3	0.3a	0.2
ICSX 1765505:H	81.7ab	1.3	18.7a	1.2	**3.6c**	0.2	**64.3b**	5.3	0.3a	0.2
ICSX 1765690:H	**76.4a**	1.3	14.8a	1.2	**3.6c**	0.2	56.2ab	5.3	-0.2a	0.2
Locale_Bentoroko _Kout	83.2ab	1.8	17.7a	1.8	2.3ab	0.3	59.5ab	7.6	-0.3a	0.3
Locale_Bougouni	83.8b	1.8	18.2a	1.8	1.6a	0.3	28.0a	7.6	-1.0a	0.3
LSD (5%)	4.071		4.0		0.6		17.1		0.8	
Genotype	70.1**		29.4ns		4.4**		1192.2**		1.5ns	
+ Genotype.Villages	91.9**		223.6**		2.4**		888.5**		0.5ns	
+ Genotype.Villages.Zones	-		-		-		-			
Residual	19.4		18.6		0.5		342.8		0.7	
Total	**41.01**		**68.6**		**1.3**		**545.2**		**0.7**	

Sub-activity GH1114-19: Use CCAFS' Climate-smart village approach to mainstream climate variability in the promotion and dissemination of Africa RISING SI interventions for sustained productivity and reduced risk in Ghana (Lead Institution: SARI)

This sub-activity aimed to identify research products for more productive, intensive, diverse, profitable, and resilient crops (cereals, legumes, and vegetables); livestock (sheep, goats, cattle, poultry, and pigs); and integrated crop–livestock farming systems. This allows to disseminate relevant information to farmers through development partners in the intervention communities. For example, SARI is reaching out to various other initiatives to ensure visibility and impact at scale and is exploring potential linkages with farmer and women interest groups as candidates that can contribute to scaling-out validated technologies and practices. SARI is also exploring linkages to ESOKO through CCAFS work; this would help provide a synergistic effort to the work that Africa RISING is doing.

In March 2020, 12 inventory workshops were held in 12 intervention communities in northern Ghana (Table 6). A total of 147 farmers participated in inventory workshops in northern Ghana. More male farmers (90) participated at the inventory workshops than females (47). The inventory workshops were to:

- Engage multi-stakeholders in the agricultural sector to take inventory of promising climate-smart crop-livestock-agroforestry practices.
- Prioritize practices for piloting in climate-smart villages through participatory action research.
- Assess the needs of various stakeholders to build their capacities in adaptation planning to promote climate-smart agriculture.

Nature of information collected during inventory workshops.

- General information on the village regarding their social set up (ethnicity, population), gender differentiation, agricultural activities, access to markets, and state of their infrastructure.
- Inventory of all promising climate-smart agronomic crop-livestock-agroforestry technologies introduced into the AR communities.
- Prioritization of promising crop-livestock-agroforestry technology according to their contribution to food security, adaptation, mitigation, and others.

Table 6. Community engagements for inventory workshops.

Region	District	Community	Male	Female	Total
Northern	Tolon	Cheyohi	9	6	15
		Tingoli	14	7	21
	Savelugu	Duko	11	6	17
		Tibali	14	6	20
Upper East	Kassena-Nankana	Nyangua	6	4	10
		Gia	8	0	8
		Bonia	5	5	10
	Bongo	Samboligo	4	7	11
Upper	Wa West	Zanko	4	4	8
		Guo	4	4	8
	Nadowli	Goli	5	5	10
		Goriyiri	6	3	9
		Total	**90**	**57**	**147**

Figure 9. Inventory workshops for men (left) and women (right) in Northern Ghana. Photo Credit: Saaka Buah/SARI.

Verification of farmers' knowledge and perception of climate change

Smallholder farmers are one of the groups most vulnerable to climate change, yet efforts to support farmer adaptation are hindered by the lack of information on how they experience and respond to climate change. More information is needed on how different types of smallholder farmers vary in their perceptions of and responses to climate change, and how to tailor adaptation programs to different smallholder farmer contexts. This study surveyed 147 Africa RISING farmers (90 males + 57 women) across 12 communities in northern Ghana to understand farmer perceptions of climate change and the impacts they are experiencing, how they are changing their agricultural systems in response to climate change, and their adaptation needs. Almost all (96%) of the surveyed smallholder farmers had observed climate change, and most were already experiencing impacts of rising temperatures, unpredictable rainfall, and extreme weather events on crop yields, pest and disease incidence, income generation, and, in some cases, food security. For example, most of the farmers reported negative impacts of climate change on crop production, and several of them reported food insecurity following extreme weather events. Of the farmers perceiving changes in climate, more than half of them indicated that they had changed their farming practices in response to climate change, with the most common adaptation measure being the use of soil and water conservation techniques, drought tolerant/shorter cycle varieties of crops, and planting of trees.

Promising sustainable intensification (CSA) practices at the project communities

Over the years, a portfolio of sustainable intensification interventions has been evaluated by Africa RISING in northern Ghana. In March 2020, SARI researchers and Africa RISING farmers in each community identified sustainable intensification 'climate-smart' interventions best suited for that community. The results over the years indicate that sustainable intensification practices preferred by farmers in the intervention communities were as follows:

- Intercropping
- Crop rotation with N fixing legume
- Crop-livestock integration
- Soil and water conservation techniques such as tie ridges, contour bunds, and earth bunds
- Drought-tolerant/short cycle seed varieties
- Integrated use of organic and inorganic fertilizers
- Non-burning

Prioritization of promising climate-smart agricultural practices: A meeting was held with AR farmers in target communities and nine identified climate-smart interventions best suited for the various communities were introduced to the farmers and AR officials in a gender-segregated focus group discussion. The farmers prioritized the different technologies based on yield and resilience potential, as well as other features they find useful. The process was as participatory and inclusive as possible, especially encouraging women and more vulnerable groups to participate. The criteria for the score ranged from zero indicating none/not at all to 10 indicating excellent/suitable. Results of the scoring indicated that there was heterogeneity in the ranking of the technologies among the sampled farmers in the gender-segregated focus group discussions. Generally, use of drought or stress-tolerant varieties, crop-livestock integration, non-burning or any practice that will increase organic matter input, integrated use of organic and inorganic fertilizer, intercropping including strip cropping, and soil and water conservation practices such as tie ridges (helps improve water and nutrient use efficiency), contour bunds, and earth bunds for crop production were scored highly relative to the other practices. According to the farmers, the practices enhance high productivity and income and reduce the probability of crop failure and the risk of income loss.

Scaling up interventions: Ongoing efforts included exploring the use of the ESOKO platform as a means of reaching out to farmers to receive seasonal weather forecast and information on sustainable intensification practices through mobile phone SMS methods. This will help improve their resilience to weather-related shocks. It will equally entail working closely with other partners to package the right messages and the timing of message delivery to the end users. It will also raise awareness on the role and benefits of the platform for both farmers and extension officers. Some of the messages will be tailored around crop agronomy, climate services, market information, and postharvest management practices.

Sub-activity GH1115-19: Identify varieties and postharvest management options for vegetable crop species with adaptation to Northern Ghana in the dry season (Lead Institution: WorldVeg)

This sub-activity is a follow up study for previous work conducted in 2018 through 2019. Dry season activities were conducted between October 2019 and May 2020. The activities included vegetable varietal and disease screening trials and postharvest management options within the Northern Region and the Upper East Region. The main objective was to evaluate farmer vegetable varieties preferences and market preferred vegetable varieties adapted to northern Ghana under irrigated conditions through farmer participatory approaches in terms of yield performance, and diseases and pests-tolerance under different types of fertilizer application rates. The activities sought to enable farmers' participatory variety selection, and adoption while promoting information and knowledge exchange among famers on good agricultural, postharvest, and processing technologies.

In Ghana, varietal trials on three vegetable crops (tomato, pepper, and onions) were conducted in five lead farmers' hubs within two communities (Tekru and Nyangua). Seed kits were also distributed to a total of 97 non-lead farmers within Gia, Bonia, and Doku communities who implemented variety demonstrations on their own farms. Replicated trials (mother trials) were conducted in the lead hubs while non-lead farmers in the villages tested a single replicate (baby trial) of the various vegetable varieties which was conducted concurrently with disease screening and postharvest losses. Six lead hubs were constructed in 2016 each with irrigation facilities (borehole equipped with drip system, two acre-fenced plots) under the management of both WorldVeg and farmers. Non-lead farmers set up demonstration fields to try a single replicate of each variety within the Upper East (UE) and Northern Regions (NR) of Ghana with three to four varieties of tomato and pepper, and seven varieties of onion to select high-yielding and disease resistant varieties in comparison to farmer local varieties. A randomized complete block design with 3 to 4 replications was adapted. The percentage of plants/plots showing a specific type of disease and insect pest attack was collected for statistical analysis.

Figure 10. Laying out of irrigation equipment in Duko Technology Park. Photo credit: Paul Zaato/WorldVeg.

Diseases and pests screening trials: In all, 24 tomato and 16 pepper WorldVeg varieties including local varieties as a control have been tested for resistance to diseases and pests in one site in the Upper East region of Ghana. Seeds of these varieties were distributed in November 2019 and seedlings were raised. Each accession of both tomato and pepper was planted in the field in two rows of 12 plants each (24 plants/plot) with a randomized complete block design replicated three times. Agronomic data (plant height, time to 50% flowering, time to 50% fruiting, and maturity and yield), pest and disease (percentage of plants showing disease or insect pest symptoms), and postharvest fruit quality of tomato varieties (size, color, and firmness) have been collected. Data will be subjected to ANOVA using JMP v15 or GenStat software. Further synthesis using the Sustainable Intensification Assessment Framework (SIAF) is still ongoing and will be presented in the next reporting cycle.

Capacity building: This was successfully conducted in Ghana on sack gardening in collaboration with UDS in Tamale in January for 15 trainers of trainees (3 women, 12 men) on vegetable production to improve upon household consumption of vegetables and to improve upon their nutrition. The construction of ZECC was completed by 8 farmers (5 males; 3 females). In addition, given the implementation of good postharvest and processing practices since January 2019, the shelf life of the vegetables is expected to increase exponentially. Work on good agricultural practices on farm fields will be conducted in Tekuru, Nyangua, and Duko but is pending due to COVID-19 pandemic disruptions.

Partnership/linkages with other institutions: In Ghana, there were some collaborative activities between WorldVeg, IITA, and UDS. WorldVeg is currently collaborating with IITA to implement soil amendment trials within the Upper East Region of Ghana. WorldVeg has also collaborated with UDS to implement nutrition-related activities in Northern Ghana. Training on sack gardening was conducted in Tamale in January for 15 trainers of trainees (3 women, 12 men) on vegetable production to improve upon household consumption of vegetables and to improve upon their nutrition. WorldVeg has also collaborated with extension agents of the Department of Agriculture to implement Africa RISING activities in Ghana. Extension agents help to monitor field activities and also supports in organizing trainings at field level.

Lessons learned

- Nursery establishment and field activities should start very early to be in synchrony with farmers.
- Only farmers who are willing to implement activities should be selected and unwilling farmers should not be forced to implement activities.
- Major mother trials should not only be concentrated in vegetable hubs where there are most times problems with water availability, they could also be established at communities with constant water availability such as the Tono irrigation site in Bonia.
- The most appropriate calendar for vegetable activities for the rainy season should start 1 June to 31 October and for the dry season it should be 1 October to 31 May.

Success story

Youth in Horticulture: The story of Jude Valentine Adda, A farmer from Gia Community in the Upper East Region of Ghana. This story can be found at: https://avrdc.org/a-young-mans-vision/

<u>Sub-activity GH1116-19:</u> Determine yield and postharvest quality of vegetables as affected by improved soil and water management practices in the dry season in Northern Ghana (Lead Institution: WorldVeg)

This sub-activity is complementary to sub-activity GH1115-19. Yield and postharvest quality of vegetables as affected by improved soil and water management practices in the dry season in Northern Ghana were determined. For this activity, a tomato trial was set-up at Duko and Nyangua technology parks in December 2019. The tomato variety PECTOMECH was used for the trial. The trial was carried out using a randomized complete block design with four replicates and four treatments. The treatments were as follows: T1 - Control (no soil amendment); T2: NPK15-15-15 fertilizer at recommended rate; T3: manure at recommended rate (5 MT/ha), and T4: NPK15-15-15 and manure fertilizer at half the recommended rates. The quality parameters for which the fruits are being analyzed include fruit diameter, moisture content, color, total soluble sugar, titratable acidity, and Vitamin C.

In relation to the work on the identification of varieties and postharvest management options of vegetable crop species with adaptation to Northern Ghana in the dry season, a total of four zero energy cooling centers (ZECCs) were installed in Doku and Nyangua technology parks (2 ZECCs per technology park: Fig. 11). The construction was a joint effort that included the participation of farmers during the first two weeks of February 2019. The ZECCs are constructed as a storage demonstration trial with farmers to extend the shelf-life of their harvested vegetables with two ZECCS in each technology park. However due to logistic challenges, the storage trial will be carried out at Duko while ZECCs constructed at Nyangua will be mainly used for training purposes. The first round of the storage trial started in the third week of March in Duko.

Figure 11. Construction of ZECCs in Duko technology park in Northern Ghana. Photo credit: Paul Zaato/ WorldVeg.

The storage trial was carried out with tomato fruits of four varieties (PECTOMECH, TROPIMECH, UC82, and LOCAL) grown by the target farmers. The red-light fruits (maturity stage 5) of the four varieties of tomato were subjected to four storage methods as treatments: fruits storage in ZECC (T1), fruits mixed with ash (1:1 w/w) and stored in ZECC (T2), fruits mixed with ash and stored at ambient conditions (T3), and fruits stored at ambient conditions (T4). A data logger was placed in each ZECC treatment and at ambient conditions to record temperature and relative humidity variations during the trial. Forty fruits of each variety were placed in a specific plastic crate to fill the top of the ZECC and monitored at 3, 6, and 9 days for weight loss, visual quality, and quality attributes (color, firmness, total soluble sugar, titratable acidity, and Vitamin C). Baseline data on quality attributes of the fruits on the day of harvest (Day 0) were performed on a separate lot of fruits. Five fruits were sampled for each experimental unit for the baseline quality analysis and also for the subsequent samplings. Sampled fruits on each sampling day were sent to the postharvest laboratory at UDS Tamale for quality analysis. Visual quality assessment was performed on each sampling day by 5 to 10 farmers using the 5-point rating scale (9 = excellent, 7 = very good, 5 = good, 3 = fair and 1 = poor) for overall quality of produce (Kader and Cantwell 2005). Table 7 depicts tomato and pepper varieties tested in Ghana.

Table 7. Lead and non-lead beneficiaries implementing varietal trials in Ghana in 2018–2019.

	Test Farmers		**Total**	**Number of Test Farmers**	
Sites	***Men***	***Women***	***Total***	***Youth <30***	***Old > 30***
Gia	15	19	34	20	15
Doku	16	14	30	15	17
Bonia	18	15	33	17	13
Total	**49**	**48**	**97**	**52**	**45**

The team is still conducting further analysis of data and will synthesize this in relation to the SIAF in the next reporting cycle.

Activity 1.1.2: *Test and disseminate a combination of improved breeds, housing, feeding, health, and breeding practices to intensify rearing of livestock (sheep, goats, pigs, and poultry) for meat, eggs, and milk production*

Sub-activity GH1121-19: Efficient feed utilization through improved feed troughs (Lead Institution: ILRI)

This sub-activity is in the 2nd year of its implementation, the key achievements during the reporting period were:

1. Data collection on the use of improved feed troughs during the rainy and early dry seasons. The data collection for the rainy season was conducted in September and October 2019 while the data collection for the early dry season took place in February 2020 in the intervention communities of Duko and Tibali in Northern region, and Gia in the Upper East region. The data collection on the use of improved feed troughs is now complete for the three seasons in the year.
2. Construction of 15 improved feed troughs using locally available materials. Five troughs were constructed per community. Each trough was constructed with local materials which cost about GHC234 compared to the improved feed troughs constructed with commercial materials which cost GHC1149. Data was also collected in the early dry season on the use of the improved troughs with local materials in Duko, Tibali, and Gia. An extra feed trough was constructed for the Africa RISING Technology Park in Duko using local materials. Two farmers in Duko constructed the feed troughs with local materials using their own resources.

Results from the use of improved feed troughs across seasons are presented in Table 8.

Table 8. Number of beneficiary farmers in the intervention communities and age statistics.

Community	Improved feed trough – commercial materials		Improved feed trough – local materials		Total	Age means* ± standard error (N =10)	Age means**± standard error (N = 15)
	Male	Female	Male	Female			
Duko, Northern region	5	5	3	2	15	50.30±1.27[a]	49.47±1.03[a]
Gia, Upper East region	5	5	3	2	15	47.40±1.30[a]	48.20±1.42[a]
Tibali, Northern region	7	3	4	1	15	47.00±1.40[a]	46.33±1.07[a]

* Age of the participating farmers in the use of traditional and improved feed troughs in the late dry and wet seasons ** Age of the participating farmers in the use of traditional feed trough in the early dry season (February 2020)

Across seasons, there was significant reduction in feed wastage with the use of improved feed troughs (Tables 9 and 10) when compared with the traditional feed troughs which implies that feed was saved by using the improved feed troughs which can be used to feed more animals. From the quantity offered by the farmers and the number of animals fed, it can be deduced that feed saved from wastage of about 500 g/day can feed one more sheep or goat as supplement. Time spent in feeding the animals was significantly lower with the use of improved feed troughs across all seasons than with the use of the traditional feed troughs (Tables 9 and 10). This implies that those feeding the animals gained about 10 minutes per day with the use of improved feed troughs. From the interview of the farmers, the participating farmers in the Northern region intervention communities (Duko and Tibali) tended to spend the extra time saved on their primary activity, i.e., farming or trading (in the case of women in Duko who cook food for sale or process rice).

Farmers in Gia, Upper East region spent the time saved working in their vegetable gardens. For the households where male children have to feed the animals or take them to grazing (in the rainy season), the children did not have to take animals to graze in the evenings because of the availability of more feed through reduction in wastage with the use of improved feed troughs. There was no significant difference in feed wastage between using the improved feed troughs constructed with commercial materials and those constructed with local materials. Given that the cost of the improved feed troughs made from local materials is a quarter of the cost of those constructed with commercial materials, it implies that an affordable improved feed trough is available for the farmers and this will enhance adoption. This is already the case in Duko where two farmers self-initiated the construction of the improved feed troughs with local materials. To facilitate the adoption of improved feed troughs with local materials, the model has been shared with Heifer International, Tamale and with the Livestock Development officers of the Northern Region and Kassena Nankana district.

Synthesis: The main conclusions from the demonstration of the use of the improved feed troughs in Duko and Tibali in Northern region and Gia in the Upper East region across three seasons are as follows:

- The improved feed troughs reduced waste significantly in all the communities and across all seasons. The percentage of waste in feeding crop residues using the traditional feed troughs varied from 18% to 37% across all seasons whereas the percentage of feed wastage using the improved feed troughs varied from almost 0% to 5%. Besides, the improved feed troughs reduced time spent feeding the animals.

- Construction of the improved troughs, especially with local materials, can be an income-generating activity for the youth.
- The cost of construction of improved feed troughs can be reduced significantly with the use of locally available materials (Fig. 12). The cost reduced from GHC1149 using commercial materials to about GHC234 using local materials. The main challenge with the improved feed troughs with local materials is the duration or lifespan which may not be more than three years whereas those constructed with commercial materials (planks and corrugated iron sheet) can last for at least six years.
- The farmers made modifications to the improved feed troughs to suit their needs which demonstrates their capacity to experiment. Modifications made included the addition of watering trough, a wooden barrier to prevent smaller animals from jumping into feeding compartment to contaminate feed, fencing around trough to keep away stray animals, addition of feed storage area above feeding compartment, and the removal of V-shaped storage area in troughs constructed with local materials as it requires more wood. There is now more space around all four sides of the trough to accommodate more animals.

Table 9. Comparison of the use of the traditional and improved feed troughs (commercial materials) for small ruminants in Duko and Tibali, Northern region, and in Gia, Upper East Region across seasons.

Variable	Duko		Gia		Tibali	
	Traditional	Improved	Traditional	Improved	Traditional	Improved
Late dry season (March/April 2019)						
Time spent feeding (min/day)	22.42 ± 1.77[a]	13.00 ± 1.23[b]	11.78 ± 0.42[a]	5.60 ± 0.13[b]	14.00 ± 0.84[a]	6.83 ± 0.41[b]
Number of animals	3.50 ± 0.16[a]	4.10 ± 0.14[a]	4.99 ± 0.10[a]	5.10 ± 0.04[a]	3.90 ± 0.15[a]	4.32 ± 0.13[a]
Quantity of feed offered (g/day)	2175 ± 87.67[a]	2213.33 ± 70.57[a]	1498.50 ± 30.35[a]	1530 ± 11.72[a]	2340 ± 88.72[a]	2532.20 ± 76.85[a]
Quantity wasted (g/day)	767 ± 45.30[a]	10.45 ± 2.04a[b]	336.68 ± 14.17[a]	4.83 ± 1.74[b]	625.78 ± 49.17[a]	10.63 ± 2.25[b]
% of feed wasted	35.26 ± 1.84[a]	0.47 ± 0.09[b]	22.47 ± 1.85[a]	0.32 ± 0.11[b]	26.74 ± 1.67[a]	0.42 ± 0.09[b]
Wet season (Sept/Oct 2019)						
Time spent feeding (min/day)	30.30 ± 1.77[a]	19.22 ± 0.73[b]	15.90 ± 0.71[a]	17.53 ± 0.45[a]	27.85 ± 0.73[a]	20.78 ± 0.82[b]
Number of animals	3.50 ± 0.17[a]	3.50 ± 0.16[a]	4.70 ± 0.08[a]	4.90 ± 0.04[a]	4.70 ± 0.08[a]	4.98 ± 0.02[a]
Quantity of feed offered (g/day)	2155 ± 94.19[a]	2100 ± 94.06[a]	2820 ± 50.02[a]	2940 ± 23.43[a]	2880 ± 46.87[a]	3004.63 ± 41.68[a]
Quantity wasted (g/day)	660.67 ± 55.98[a]	92.33 ± 16.59[b]	594.67 ± 31.29[a]	16.00 ± 6.14[b]	1071.15 ± 62.06[a]	132.40 ± 31.94[b]
% of feed wasted	30.66 ± 1.91[a]	4.40 ± 0.79[b]	21.09 ± 1.31[a]	0.54 ± 0.22[b]	37.19 ± 2.04[a]	4.41 ± 1.06[b]
Early dry season (February 2020)						
Time spent feeding (min/day)	28.88 ± 1.00[a]	14.08 ± 0.43[b]	25.55 ± 0.86[a]	15.08 ± 0.49[b]	27.85 ± 0.72[a]	17.50 ± 0.47[b]
Number of animals	3.70 ± 0.15[a]	3.70 ± 0.15[a]	4.60 ± 0.09[a]	4.60 ± 0.09[a]	5.20 ± 0.08[a]	5.20 ± 0.08[a]
Quantity of feed offered (g/day)	2220 ± 92.75[a]	2220 ± 92.75[a]	2760 ± 51.81[a]	2760 ± 51.81[a]	3120 ± 46.86[a]	3120 ± 46.86[a]
Quantity wasted (g/day)	723.08 ± 31.55[a]	1.54 ± 0.02[b]	521.59 ± 24.42[a]	2.34 ± 0.0.65[b]	899.50 ± 30.29[a]	1.83 ± 0.23[b]
% of feed wasted	32.57 ± 2.29[a]	0.07 ± 0.01[b]	18.90 ± 1.13[a]	0.08 ± 0.03[b]	28.83 ± 1.04[a]	0.06 ± 0.01[b]

Table 10. Comparison of the use of the traditional, improved feed troughs with commercial materials and improved feed troughs with local materials for small ruminants in Duko and Tibali, Northern region, and in Gia, Upper East Region, Ghana in early dry season (February 2020).

Variable	Traditional (n = 15)	Commercial materials (n = 10)	Local materials (n = 5)
Duko			
Time spent feeding (min/day)	27.50 ± 0.82^{a}	14.08 ± 0.43^{b}	13.27 ± 0.54^{b}
Number of animals	3.55 ± 0.13a	3.70±0.15^{a}	3.20 ± 0.22^{a}
Quantity of feed offered (g/day)	2120 ± 76.55^{a}	2220±92.75^{a}	1920 ± 129.93a
Quantity wasted (g/day)	689.56 ± 32.41^{a}	1.54±0.02^{b}	13.33 ± 8.04^{b}
% of feed wasted	32.53 ± 1.77^{a}	0.07±0.01^{b}	0.69 ± 0.31^{b}
Gia			
Time spent feeding (min/day)	27.77 ± 0.90^{a}	15.08 ± 0.49^{b}	13.03 ± 0.61^{b}
Number of animals	4.07 ± 0.12a	4.60 ± 0.09^{a}	3.00 ± 0.20^{b}
Quantity of feed offered (g/day)	2440 ± 71.45^{a}	2760 ± 51.81^{a}	1800 ± 122.05^{b}
Quantity wasted (g/day)	448.94 ± 25.43^{a}	2.34 ± 0.0.65^{b}	6.00 ± 0.32^{b}
% of feed wasted	18.40 ± 1.30^{a}	0.08 ± 0.03^{b}	0.33 ± 0.16^{b}
Tibali			
Time spent feeding (min/day)	31.53 ± 1.08^{a}	17.50 ± 0.47^{b}	17.70 ± 0.81^{b}
Number of animals	5.13 ± 0.05^{a}	5.20 ± 0.08^{a}	5.00 ± 0.24^{a}
Quantity of feed offered (g/day)	3080 ± 31.73^{a}	3120 ± 46.86^{a}	3000 ± 50^{a}
Quantity wasted (g/day)	885.78 ± 28.03a	1.83 ± 0.23^{b}	2.41 ± 0.02^{b}
% of feed wasted	28.76 ± 0.95^{a}	0.06 ± 0.01^{b}	0.08 ± 0.02^{b}

Figure 12. Picture of the improved feed trough constructed with local materials. Photo credit: Sadat Salifu/ARI.

Problems/challenges and measures taken: There was no challenge in conducting the activities on improved feed troughs in the intervention communities.

Partnership/linkages with other projects: The planned activity on efficient feed utilization through improved feed troughs was based on success stories of a similar intervention by the Africa RISING project in Ethiopia.

Lessons learned: From the sub-activity on improved feed troughs, the main lesson learned was the need to be flexible in the implementation of a given technology being introduced to farmers so as to accommodate their modifications which can facilitate better adoption.

The improved feed troughs could be a success story in the near future based on the general enthusiasm shown by the farmers in the intervention communities in using it and the opportunity of constructing it by the youth.

Activity 1.1.3: *Test and disseminate integrated crop-livestock-soil and agroforestry systems to increase and sustain productivity and reduce risk.*

Sub-activity: MA1131-19: Risk management and informed decision making towards sustainable intensification of crop-livestock systems (Lead Institution: WUR).

Analysis, interpretation, and discussion of achievements

This study aimed to assess the state of representative farming systems in southern Mali in the near future (2027) based on biophysical and socioeconomic trends in sub-Saharan Africa and thereby to identify promising pathways that enable SI. Accordingly, a model was developed to assess SI in the baseline situation and in six subsequent scenarios, based on incremental policy intervention and agricultural intensification strategies, for 411 smallholder farms in the 'old cotton basin' in southern Mali.

The model checked for different SI indicators from four domains of sustainability. Under the assumption that intensification is the main objective of SI in sub-Saharan Africa, three promising pathways were identified. Firstly, successful promotion of contraceptives combined with the creation of job opportunities outside agriculture reduced the pressure put by the rapid population growth on smallholder systems. Secondly, closing the yield gap up to 85% of the water-limited yield through different means of sustainable water management and conservation distinctly intensified the system. However, trade-offs with the environmental domain were identified. Lastly, the implementation of inventory credits for cereals increased the profitability but more importantly reduced farmers' dependency on the cotton sector. Eventually, the research underlines that only a combination of multiple potential pathways can truly enable SI.

Table 11. Hazards including the farmers' definitions given during focus group discussions.

Hazard	Farmers definition	Complementing info
Late onset rain	After 1 June (some farmers mentioned 15/6)	Global Yield Gap Atlas definition (GYGA): > 20 mm within 7 consecutive days in the sowing window (Koutiala 10 May–10 June)
Uneven distribution of rain	Dry spells from 1 to 2 weeks without rain. Farmers mentioned it also depends on soil type, black soils can resist longer. Some farmers claimed that in the middle of the rainy season, dry spells can last up until 3 weeks without doing too much harm	
Low total rain	< 750–800 mm	
Household members falling sick; animals falling sick		Insufficient access to labor affects field management. It can lead to fields being sown relatively late

Results of the research on risk perception and risk management strategies of farmers are used to define the hazards and management options that are most relevant to the area. Initially we had foreseen to quantify the effect of shocks on-farm production to explore the effects of risk mitigation strategies on-farm production stability for different farm types. Farmers indicated the hazards they are concerned about. From this list of 24 hazards, the hazards linked to a production risk that was perceived as highest by farmers are indicated in Table 11.

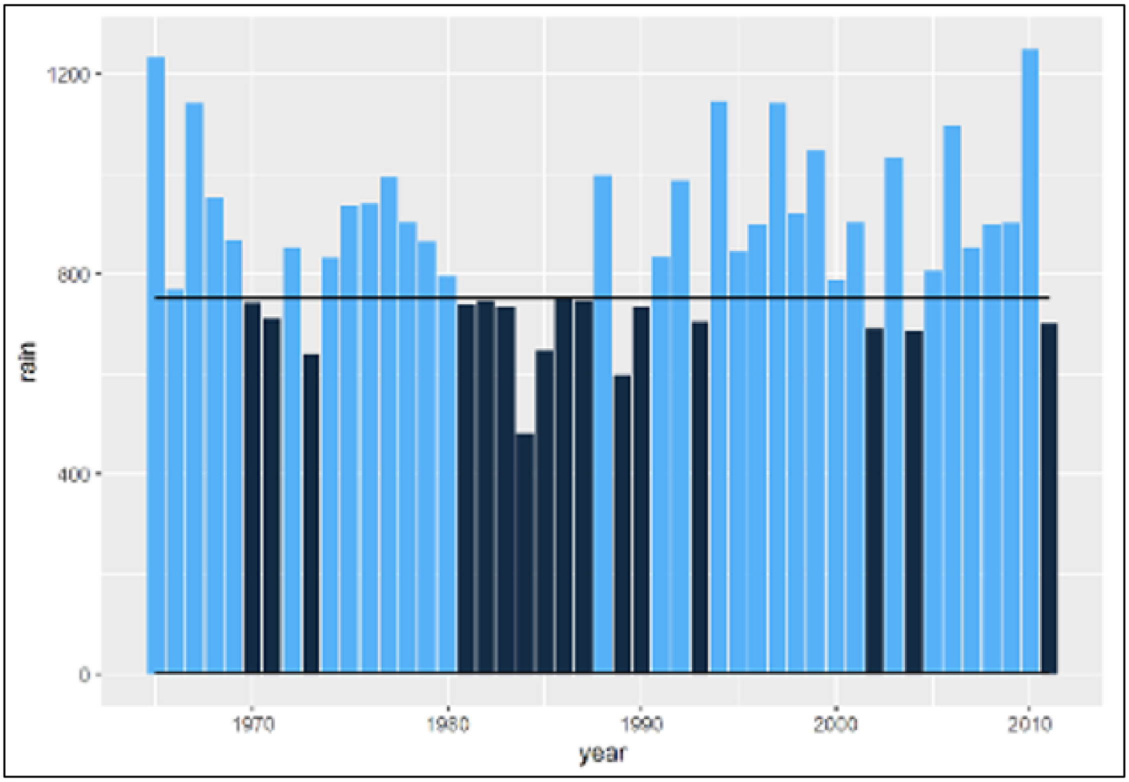


Figure 13. Total rainfall amount per year at N'Tarla research station based on available data (1965–2011).

As a first step in the quantification of risk, the frequency and severity the climate-related hazards are being assessed using rainfall data from the weather station in N'Tarla for the period of 1965–2011. In Figure 13, a sample occurrence of one of the hazards is visualized. Farmers assessed years with less than this amount of rainfall as bad years. In the period 1965–2011, this occurred in 34% of the years (16 out of 47 years) (Figure 13). Further details on this sub-activity will be provided in the final report.

Output 1.2: *Integrated management practices and innovations to improve and sustain productivity and ecosystems services of the soil, land, water, and vegetation resources are developed and disseminated with farmers and development partners in the intervention communities*

Activity 1.2.1: *Test and disseminate land, soil, and integrated land–soil technologies and practices to improve and sustain productivity and ecosystems services at the farm and landscape/watershed levels*

Sub-activity GH1211-19: Assessing buffer and adaptive capacity to harness the resilience of different farm types (Lead Institution: WUR).

In this sub-activity, we provide an update on written manuscripts and master's thesis as well as progress on nutrition and resilience-related activities as well as evaluation of access to agricultural interventions.

1. Written manuscripts, reports and presentations
   PhD graduate Mirja Michalscheck has submitted two papers from her thesis. A paper entitled 'Beneath the Surface: Intra-household Dynamics and Trade-offs in Resource Allocation Decisions by Smallholder Farmers' was rejected by World Development. Currently we are revising the paper and it will be resubmitted to another journal shortly. The second paper entitled 'Land use decisions: by whom and to whose benefit? A serious game to uncover dynamics in farm land allocation at household level in Northern Ghana' has been published in Land Use Policy.

   Dr M. Michalscheck and MSc student Dorien Jansen have conducted fieldwork for an analysis of the resilience of low, medium and high resource endowed farms in UW, UE, and Northern region of Ghana. The student report has been completed and presented in a student colloquium.

   In May and June 2019, a case study was held to investigate how interactions and exchanges among villagers govern who is able to benefit from agricultural development initiatives and who is less or not able to. In total, 62 semi-structured interviews and four focus group discussions were held across two Africa RISING villages—Duko (Northern Region) and Nyangua (Upper West Region)—and four villages targeted by N2Africa in Ghana. The case study was exploratory work that formed the basis for further PhD research in the same villages. The full output of this case study can be found in a report entitled "Access to plot- and community-level agricultural development technologies", that was shared in September 2019.

2. Nutritional work updates

Farmer perceptions of the nutritional status of their household:

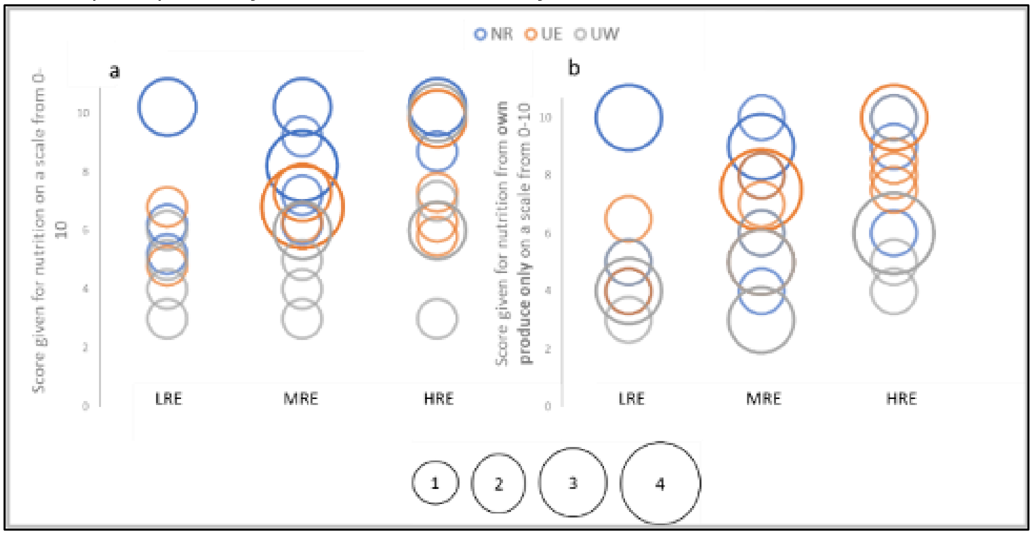


Figure 14. (a) Scores provided by low (LRE), medium (MRE), and high (HRE) resource-endowed farmers on how they perceive their general nutritional situation in a normal year with a score 10 for excellent and score 0 for dreadful. The different colors indicate the regions. The size of the circles indicates the number of respondents that gave that answer. The scale can be seen at the bottom of the figure. (b) Same figure but now for perceived nutritional situation from their own produced food only.

Modelled effects of disturbances and resilience:

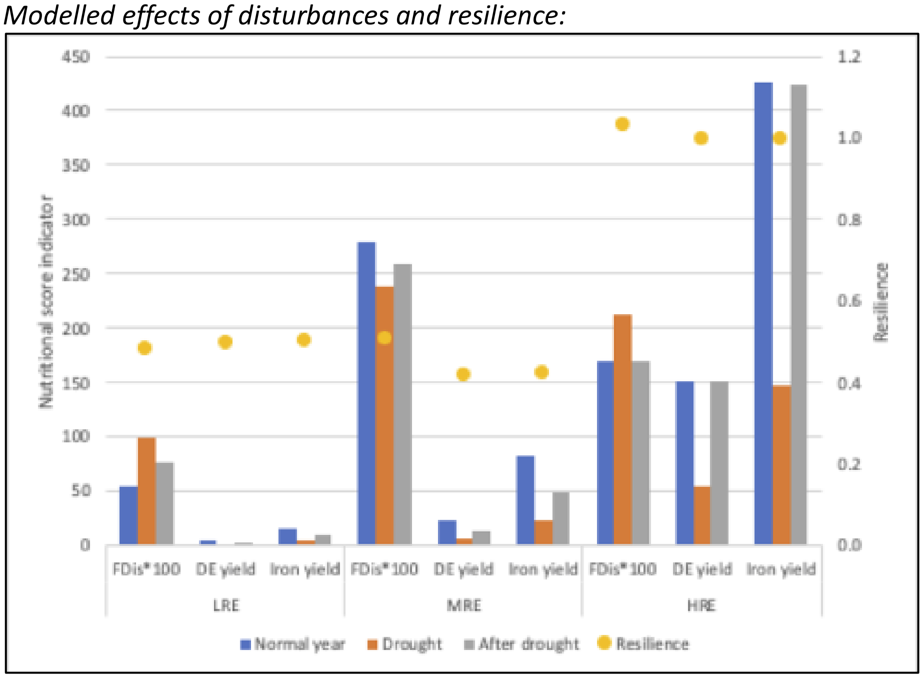


Figure 15. Three nutritional indicators (functional dispersion, dietary energy, and iron yield) for the three modelled farm types in a normal year, during a year with drought, and the year after drought, and the value for resilience for each of these indicators per farm type. FDis values are multiplied by 100 so the differences are better visible.

Willingness of farmers to adjust their farms in subsequent years:

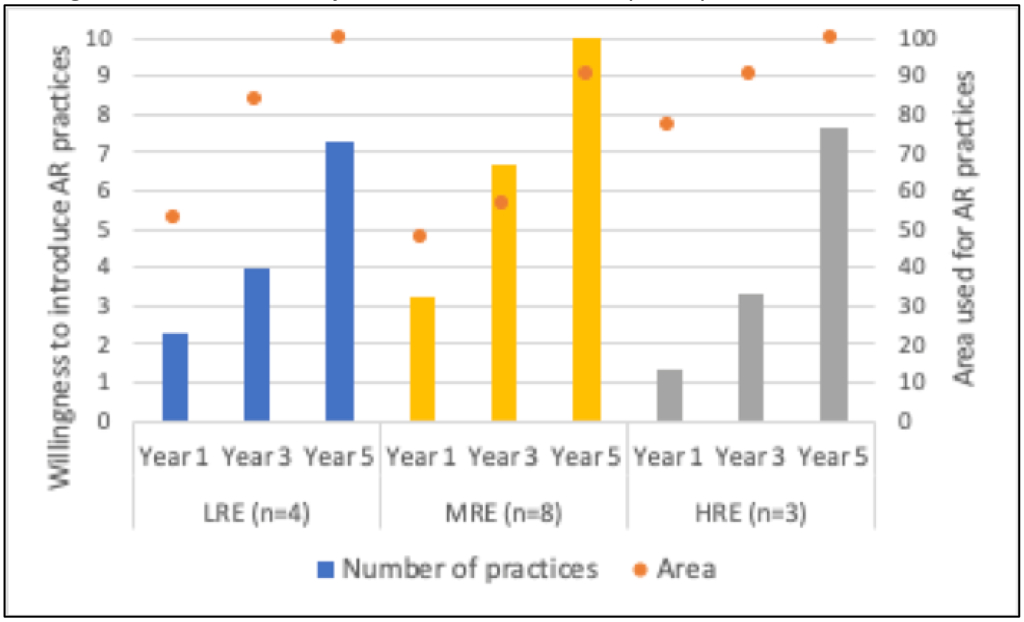


Figure 16. Willingness of the three farmer types in the NR to introduce new practices and the areas in which they would do that in 1, 3, and 5 years according to the survey results.

3. Resilience of productivity and nutrition for different types farms
The diet of smallholder farmers in Northern Ghana is vulnerable to disturbances such as drought and a price shock. This has implications for personal health and national progress. It is unknown how the farmers can best arrange their farm to be more nutritionally resilient to these disturbances based on their own production. This research project investigated the possibilities to improve nutritional resilience for smallholder farmers from different resource endowment levels and translated these possibilities into individual farm development pathways. The whole farm model FarmDESIGN was used to find the steps in the pathways and they were validated with information from a survey held with 45 men and women involved in farming from Africa RISING intervention communities in the three regions of Northern Ghana and three focus group discussions.

Between the regions' different initial nutritional situations, different sources of resilience against disturbances were observed due to the presence of dry season vegetable gardens or SuSu groups where farmers can take a loan to afford inputs. Nutritional situation was expressed in indicators capturing the diversity, quantity, and quality of the diet. The proposed pathways had in common that they chose sustainable intensification practices of growing crops or raising animals, over traditional ones, due to their higher productivity at limited extra costs and labor input. Pathways developed for one of the regions could not be generalized to households of the same resource endowment level in other regions because they depend on the current farm practices rather than on resource endowment. Nutritional resilience mainly comes from diversity in the crops grown and the ability to store food products. Infrastructure and short-term production of credit were important as well. With the knowledge obtained, Africa

RISING can improve its trainings with more attention for education on nutrition and how to grow nutritional food products for both men and women.

4. Access to plot- and community-level agricultural development technologies
   Three important determinants were identified that require further research to allow for better targeting and tailoring of interventions for sustainable and equitable intensification.

   Firstly, **access to interventions** provided by projects is not uniform across and within communities. Across communities, projects tend to select communities close to main roads and larger towns. Within communities, projects often work with existing groups while these exclude marginalized people—whether based on age, gender, health, or ethnic background. Similarly, if sampling of beneficiaries relies on a list of names put forward by villagers, those who are more pro-active and/or powerful are more likely to become direct project beneficiaries. These direct beneficiaries tend to share information with others—often via groups—but indirect training via friends is considered inferior to direct training from a project. Direct beneficiaries are therefore likely to benefit most from a project.

   Secondly, the **capacity to implement the intervention** is dependent on the ability of households or individuals to mobilize the required resources at the right time. The beginning of the rainy season and the beginning of the dry season are particularly busy periods in which there is a lot of competition for labor. Being part of a group for labor and/or having a strong social position improves access to labor. Free labor is becoming scarcer as many laborers prefer a cash payment over reciprocal labor in return for their work. In terms of capital investment, maize is the prioritized crop. Other crops may receive less or no inputs if capital is limiting. Capital availability fluctuates highly throughout the year. Critical periods occur when school fees need to be paid and at the start of the cropping season. Saving is facilitated in some groups, and through access to tools that allow for the storing of produce.

   Thirdly, **the capacity to benefit from implementation**—for instance in terms of higher income—is dependent on access to facilities that can improve the value and profitability of harvested produce. Access to such facilities (for instance, vehicles, storehouses, and processing machines) is often governed at the community level. Some people (collaboratively) own such facilities and are able to make the rules that determine access and use, and others have to adhere to these. Access is limited by the conditions for use and by the small number of these facilities. Those with a strong social position and a large investment capacity are likely able to access and use such facilities and improve the profitability of their farming practices.

   These notions should be carefully considered by project initiatives to avoid the risk of structurally including the financially and socially better-off households or individuals and not the more marginalized, as diffusion of technologies and benefits it not a given.

Sub-activity MA1211-19: Determination of cropping management factors using empirical relations, GIS, and Remote Sensing tools in two agroecologies of Mali (Lead Institution: AMEDD)

This sub-activity is in its first year in Mali. The objectives of this sub-activity are: (i) determination of cropping management factors using empirical relations, GIS, and Remote Sensing tools in two agroecologies of Mali; (ii) assess the impact of soil erosion on landscape soils productivity; (iii) evaluate variations of plant available nutrients, such as carbon, nitrogen, phosphorus, and potassium in different agroecologies under different land use systems; (iv) identify areas affected by natural and anthropogenic changes; and (v) provide appropriate guidance and recommendation on environmental protection to help increase crop productivity and reduce soil degradation.

Analysis, interpretation, and discussion of achievements

Five major land use categories were identified at a district scale in Bougouni and Koutiala. These are (i) agricultural land, (ii) forest, (iii) natural vegetation, (iv) bare land, and (v) water bodies. In Koutiala, natural vegetation occupied the largest area with an estimated area of 574,564 ha (54%), followed by agricultural land with an area of 360,157 ha (34%). Others make the rest, i.e., bare land 68 673.6 ha (6.4%), forest 45 770.8 ha (4.3%) and water body 16 159.8 ha (1.3%). In Bougouni district, natural vegetation occupies 57.5% of the total landmass (1,247,022.8 ha), followed by agricultural land (427,820.7 ha, 19.7%). The forest land occupies 246,888.9 ha or 11.4%. Bare soils and water bodies occupy an area of 228,777.4 ha or 10.5% and 19 265.4 ha or 0.9%. This result revealed that natural vegetation represented more than 50% of the total landmass in the two districts while agricultural land had occupied an average of 25% in the two districts. The combined slope length and steepness factor (LS) for Koutiala varied from 0 to 1, indicating a slope from flat to gentle. The computed LS factor showed low soil erosion loss. The estimated mean annual soil loss in Koutiala ranged in the FAO tolerable soil loss limits of 4.20–7.20 t/ha/y for soils with deep depth[13]. In Bougouni district the rate of soil loss reached a maximum of 43.8 MT/ha/year. The high rate of soil loss may be attributed to the higher rainfall relative to Koutiala district.

Sub-activity GH1212-19: Assess the impact of soil and water conservation interventions in a maize-cowpea living mulch system (Lead Institution: KNUST)

This sub-activity has been completed and was ongoing for the last three years. The main objective was to monitor soil moisture retention and depletion cycles and nutrient fluxes within cropping systems in selected soil and water conservation practices, and crop growth trends. The study was conducted in four communities: Tibali and Duko in the Savelugu District, Tingoli in the Tolon District, and Cheyohi in the Kumbungu District, all in the Northern Region of Ghana. Four different cowpea living mulch systems and three maize varieties with different maturity types as the treatments were established on 12 plots (3 m by 4 m per plot) in the respective communities as replicates. The cowpea living mulch systems were: (1) no living mulch (**NLM, T1**); (2) maize + cowpea planted same day (**SD, T2**); (3) maize + cowpea planted 1 week after planting maize (**A1WK, T3**); and (4) maize + cowpea planted 2 weeks after planting maize (**A2WK, T4**). The maize varieties were (i) extra-early (Abontem-**V1**, 75-80 days), (ii) early (Omankwa-**V2**, 85-90 days), and (iii) medium (Obatanpa-**V3**, 110-120 days) (Fig. 17).

[13] FAO, 1984. FAO UNESCO Soil Map of Africa. http://www.fao.org/3/as357e/as357e.pdf

Agronomic activities: For this reporting period, field lay out in the four communities was undertaken between 1 and 4 July 2019. This was after field preparation by ploughing within the last week of June. Planting of maize (3 seeds per hole) and cowpea (2 seeds per hole) in accordance with the treatments took place between 8 and 31 of July 2019.

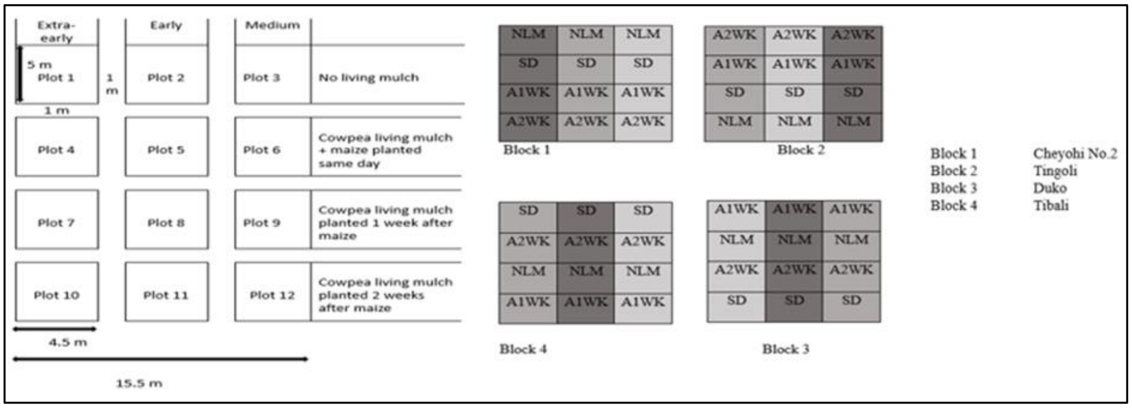


Figure 17. Sample of the treatments layout (left) and randomization (right) per community.

Composite soil samples were collected from the four community fields at planting (10 and 11 July 2019) and at harvest (14 and 18 October 2019) and were taken to the laboratory to determine their hydraulic properties. Basal (compound fertilizer) application was done in the fourth week of July 2019, about 5 g per plant. Top-dressing (urea) application of the same quantity was done in the first week of September 2019. Weeding was done between August and September 2019 by hoeing.

Data collection: Soil moisture data were taken with the Diviner Probe through 5 cm diameter PVC access tubes, one installed per plot in all four communities. The data was logged on to the display unit. Access tube installation which reached a maximum average depth of 45 cm in all four communities was completed on 9 August 2019. All the 48 plots were mapped according to Diviner profiles on 19 August and taking of soil moisture readings at the four communities started that same day. The readings were taken twice a week for each community up to January 2020. The moisture readings between August and October 2019 which is the actual growing season were downloaded and converted to volumetric water content values after a gravimetric calibration based on the different field sites. Moisture readings data between November and January are being analyzed.

Growth parameters of maize and cowpea were collected at harvest. Five plants in the middle rows were randomly sampled per plot and the data taken in all four communities. The maize parameters taken were plant height (cm), stem girth (cm), number of leaves, number of cobs, length and width of leaves (cm), and grain yield (kg/ha). The leaf area index was calculated using the length and width of the leaves. Cowpea growth parameters taken were the ground (area) coverage (%) and number of pods. The area of coverage was taken with a 0.5 m by 0.5 m quadrat. The extent of canopy cover on the ground between the maize plants by the cowpea leaves has an effect on moisture loss and retention.

Four lysimeters were installed per community, one in each middle plot of the four community fields. Their function was to collect soil leachate from the ground for nutrient analysis in the laboratory. These lysimeters were first filled with 500 ml of water on 29 and 30 July 2019 to create an interface between the soil and the porous ceramic cup at the bottom of the lysimeters. Suction pressure of 60 cb was then applied to all the lysimeters after labelling between 19 and 21 August 2019. Soil leachate collection started from 26 August and has been collected and labelled for five weeks. These soil leachate samples were refrigerated and taken to the laboratory for nutrient (Nitrogen N, Phosphorus P, Potassium K) analyses. The lysimeter labels are CH # for Cheyohi, TG # for Tingoli, DK # for Duko, and TB # for Tibali (Fig. 18). Results of the analysis are yet to be received due to the COVID-19 lockdown disruptions.

Communi	Cheyohi			Communi	Tingoli	
plot 1	**CH 1**	plot 3		plot 1	**TG 1**	plot 3
plot 4	**CH 2**	plot 6		plot 4	**TG 2**	plot 6
plot 7	**CH 3**	plot 9		plot 7	**TG 3**	plot 9
plot 10	**CH 4**	plot 12		plot 10	**TG 4**	plot 12
Communi	Duko			Communi	Tibali	
plot 1	**DK 1**	plot 3		plot 1	**TB 1**	plot 3
plot 4	**DK 2**	plot 6		plot 4	**TB 2**	plot 6
plot 7	**DK 3**	plot 9		plot 7	**TB 3**	plot 9
plot 10	**DK 4**	plot 12		plot 10	**TB 4**	plot 12

Figure 18. Layout of the position and labels of lysimeters in each community.

Soil moisture results: The weekly data in volumetric water content units (%) were plotted against time with depth to determine weekly changes in trends of moisture content contained in the soil under the different treatments for the different communities over the growing period (Fig. 19). The changes (i.e., increase/decrease) in moisture content (soil moisture flux in mm) as at the last week for the different treatments in the different communities were also determined (Fig. 20).

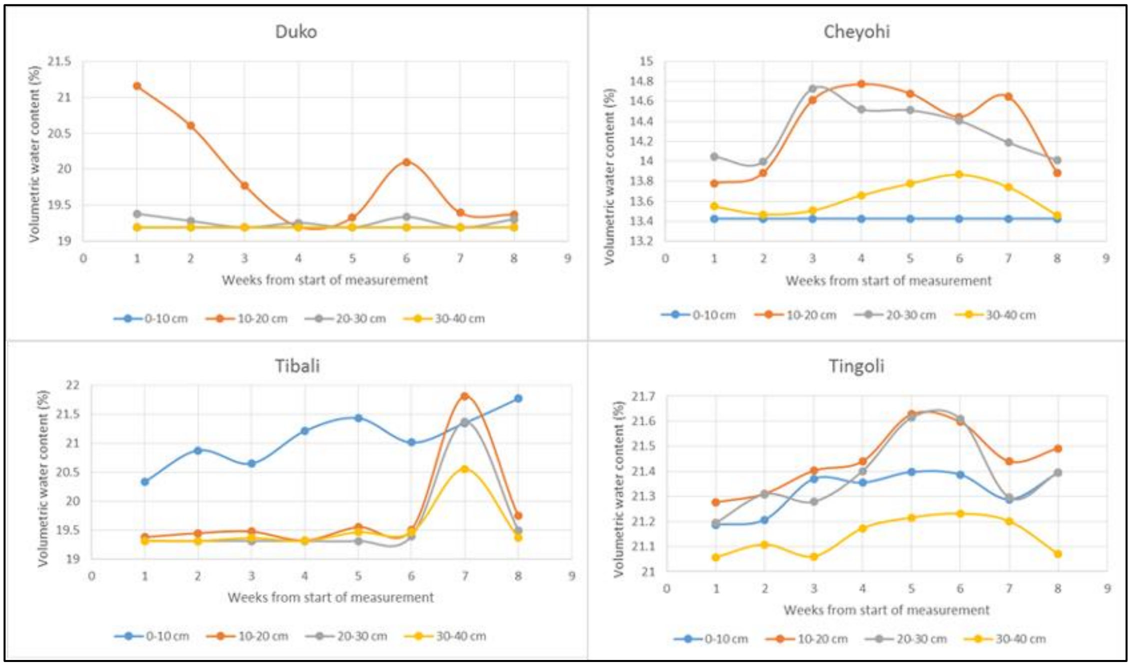


Figure 19. Volumetric water content for cowpea planted one week after planting medium maize variety for the different communities.

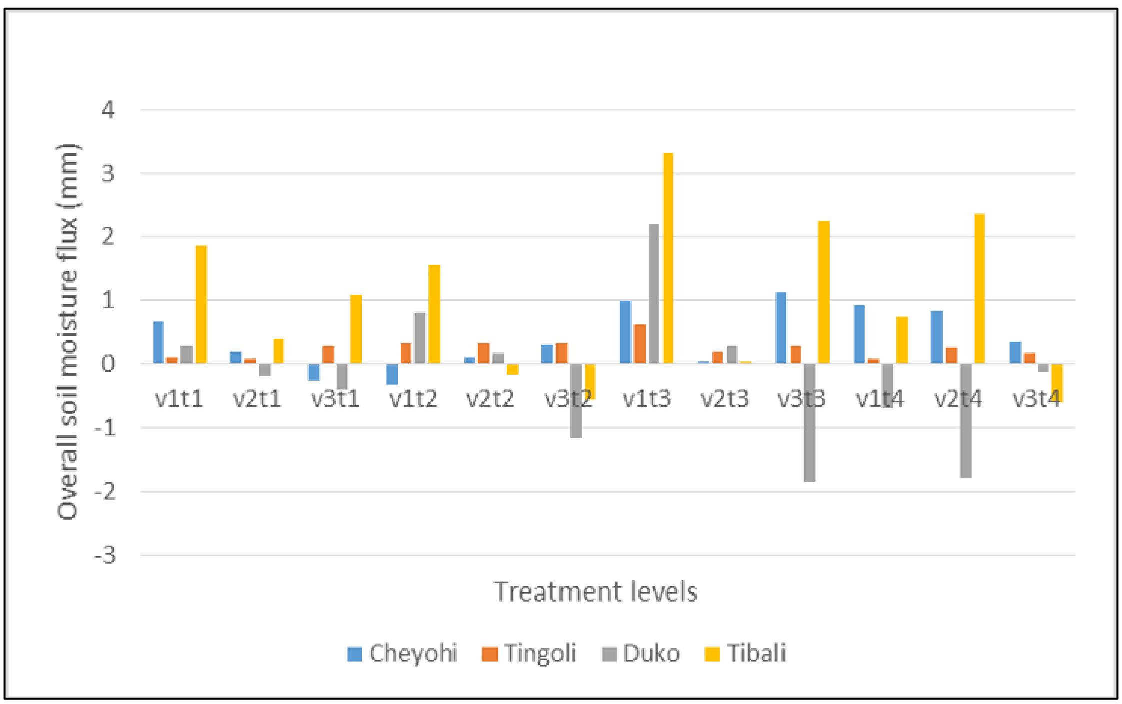


Figure 20. Total moisture flux at the different communities for the different treatments.

Growth parameters: Data of the growth parameters of both maize and cowpea were analyzed using GENSTAT statistical package (12th edition) under a two-way ANOVA with a randomized block design. The four cowpea living mulch levels and three maize varieties were the factors, and the four communities the blocks. Analysis was conducted to find the least significant difference of 5%. Apart from the stem girth which was significantly higher under the no living mulch system than the other three treatments, there were no significant differences ($p < 0.05$) observed on the effect of cowpea living mulch levels on plant height, number of leaves and leaf area index, number of cobs and yield. The differences on the effect of the maize varieties were significant for plant height, stem girth, number of leaves and grain yield, but not significant for the leaf area index and number of cobs (Fig. 21).

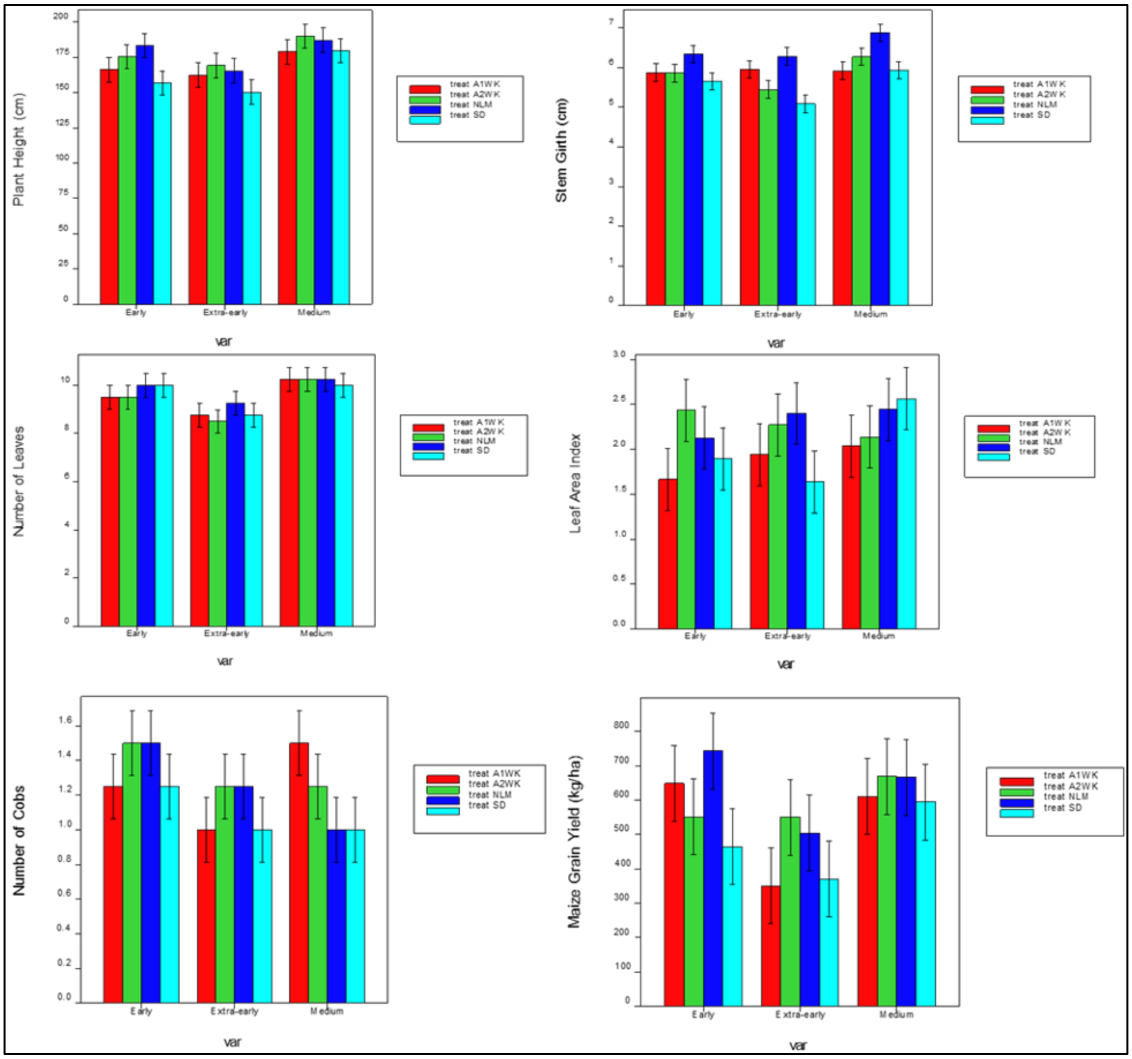


Figure 21. Analysis of effect of the treatments on maize growth parameters at harvest.

There were significant differences in the effect of the cowpea planting period on the ground cover achieved. However, the number of pod differences were not significantly different (Fig. 22). Following is the plotting of the results.

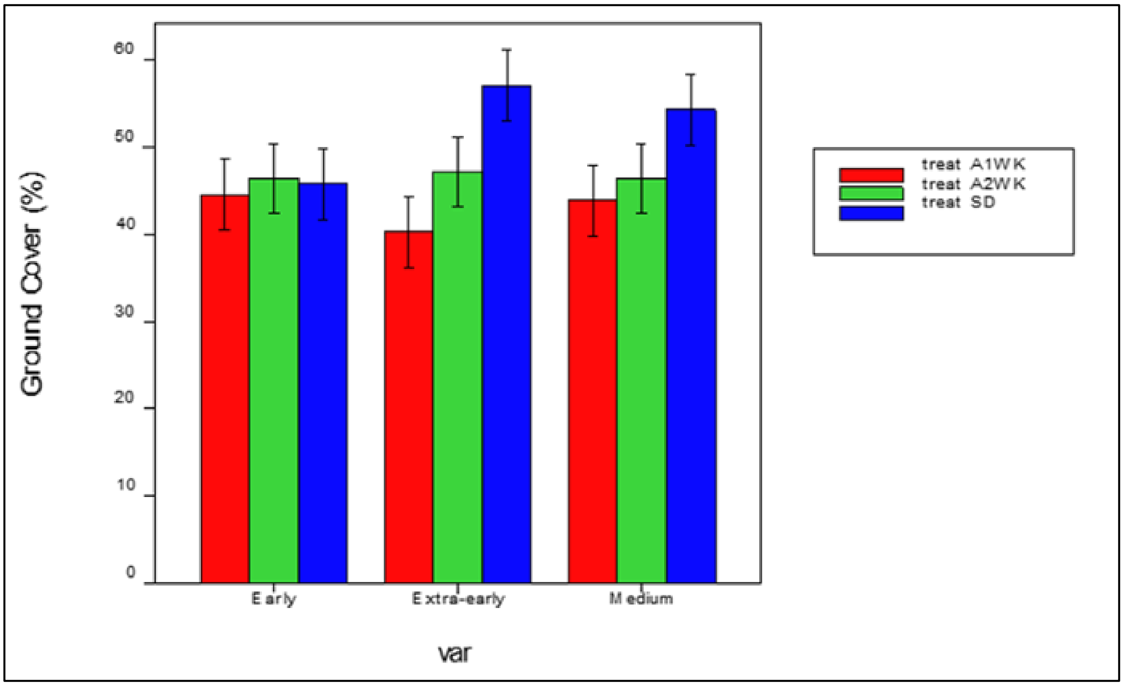


Figure 22. Effect of period of cowpea planting on percentage ground cover.

Ongoing Activities: The results are being discussed to conclude on the set objectives. The benefit/impact of the different maize-cowpea intercropping on moisture storage and retention will be discussed, as well as the effect of the different intercropping systems on maize growth. Recommendations will then be made accordingly for consideration in further studies.

Future work: Analysis on nutrients is ongoing from samples that were submitted to SARI and dry season trends data is being analyzed.

Figure 23. Selected scenes of field activities undertaken during the quarter. Photo credit: Ernestina Annan/KNUST.

Sub-activity MA1212-19: Improving crop-livestock productivity and household income through the use of contour bunding and agroforestry options (Lead institution: IER-Mali)

This sub-activity is conducted in Mali with an overall objective of improving crop and livestock productivity and household income through the use of contour bunding technology (CBT) and agroforestry options.

Analysis, interpretation, and discussion of achievements

During farmer field days, farmers observed crops and trees in contour bunding (CB) plots more developed than those in the non-CB plots. The importance of CB technology, fodder plants production, implementation of micro-dosing, and intercropping systems was discussed with farmers during FFD. Non-participating farmers in Africa RISING needed to take-up these technologies and asked to have collaboration for the 2020 growing season. Farmers who are already experiencing the CB technology wanted to expand the application of the technologies as well. Farmers were trained on how to protect the planted seedlings with wooden fences at the end of the rainy season before the dry season open grazing starts (Fig. 24).

Figure 24. Tree seedlings protected by wooden fences in the farmers' fields in Koutiala. Photo credit: Kalifa Traore/IER.

Effect of CB technology on soil erosion and fodder plants growth: Data obtained over three years (2017–2019) showed that the rate of soil erosion loss in NCB plots (37 835 kg/ha) was significantly higher than ($p < 0.01$) the loss from CB plots (16 037 kg/ha). Further results showed that fodder biomass in CB plots was significantly ($p < 0.05$) higher than that in NCB plots. After three years of growth, the mean value of Gliricidia weight was 15.33 kg/plant in CB parcels and 12.32 kg/plant in NCB parcels. The biomass of Leucaena on CB plots was 10.9 kg/plant and 8.8 kg/plant in NCB plots. Further conclusive details will be provided in the final report.

Activity 1.2.2: *Test and promote water management technologies and practices to increase water productivity in the small-scale crop–livestock farming systems under rainfed and irrigated conditions*

Sub-activity GH1221-1: Evaluate the technical and agronomic performance of Bhungroo and solar-energy drip irrigation system in the Upper East Region of Ghana (Lead Institution: IWMI)

The sub-activity (GH122-19) was implemented during the 2019/2020 dry season with the main objective of evaluating the technical and agronomic performance of solar-powered drip irrigation system in two communities. The experiment was started at the end of December 2019 and field activities will be completed at the end of April 2020. Although there were no planned milestones during this reporting period, several activities were implemented between October 2019 and February 2020. Some of the major activities include:

- Field experiment executed (see Annex 1) and data collection is ongoing and to be completed at the end of April.
- Harvesting of tomato and onion will be completed at the end April 2020 and the results will be presented during the review and planning meeting in May 2020.

There were capacity building activities where one IWMI researcher participated in the 2nd IRAD conference organized by UDS from 25 to 27 February 2020.

In relation to challenges encountered and measures taken against them, recently there were deficiency and disease symptoms observed on the tomato fruits (at Seepat site) and discussion is in progress with WorldVeg pathologists (Wubetu Legesse) to find out the causes and solutions. In addition, our solar panel was damaged by a windstorm on 24 March 2020 at Gorogo community. However, we quickly fixed it the next day in collaboration with Pumptech PLC (private sector).

This sub-activity is linked with other projects:

- IWMI collaborated with WorldVeg on the selection of onion and tomato varieties and identification of disease/deficiency symptoms in Seppat site.
- The Africa RISING project is working with Water Land and Ecosystem (WLE) CRP and demonstrated Bhungroo-based solar irrigation system in the Upper East Region of Ghana.

There are a couple of lessons learned during this quarter while working with the private sector such as Pumptech. It is critical to collaborate with them since they are locally present and can operate and scale out solar irrigation within and outside the target communities.

The team drafted a manuscript: Zenebe Adimassu, Bedru Balana, Richard Appoh, Eric Nertey (2020). The use of the wetting front detector as an irrigation-scheduling tool for pepper production in the Upper East region of Ghana: Evidence from field experiment and farmers' views (*under review*).

Figure 25. Overview of field activities with a solar pump and established tomatoes (left) and onions (right) in Northern Ghana. Photo credit: Zenebe Adimassu/IWMI.

Sub-activity MA1221-19: Improved irrigation technologies for efficient and sustainable agricultural water management in rural Mali (Lead institution: WorldVeg)

This sub-activity is being conducted in Mali. The key objectives of this study are to: (i) evaluate existing initiatives and constraints in using efficient and sustainable water management practices; and (ii) identify public-private partnerships through multi-stakeholder approaches to avail and promote solar energy pumps and improved irrigation technologies to smallholder farmers.

Analysis, interpretation, and discussion of achievements

The nine villages where surveys on improved irrigation technologies were conducted are Madina, Dieba, Sibirila, and Flola in Bougouni district, and M'pessoba, Sirakele, Zanzoni, Nampossela, and N'golonianasso in Koutiala district. Sample size was calculated based on the total number of households in the two districts (Bougouni and Koutiala) and data obtained from district health bureaus (Table 12). The total number of respondents as per standard statistical random sampling empirical equations were 302 and 335 respondents for Bougouni and Koutiala, respectively. However, considering the cost of time and resources we applied 20% of sample size for each village. During the survey it was realized that solar pumped irrigation practices were mostly owned by female members of the household who represented 68% and 60% of respondents in Bougouni and Koutiala, respectively (Table 12). Presently data analysis is ongoing, and results will be included in the final report.

Table 12. Targeted and achieved sample size per village.

Villages	Number of households*	Sample size**	Targeted 20 % of sample size	Female respondents	Male respondents	Final interviewed
Bougouni District						
Madina	523	111	22	16	6	22
Flola	311	66	13	7	6	13
Sibirila	234	50	10	6	4	10
Dieba	353	75	15	12	3	15
Total	**1 421**	**302**	**60**	**41**	**19**	**60**
Koutiala District						
Zanzoni	286	38	8	6	2	8
Sirakele	370	49	10	7	3	10
Nampossela	175	23	5	3	2	5
N'golonianasso	510	67	13	9	4	13
M'pessoba	1200	158	32	6	10	16
Total	**2 541**	**335**	**68**	**31**	**21**	**52**
Grand total	**3 962**	**637**	**128**	**72**	**40**	**112**

*Source: Census obtained from district health offices (2020)

**Sample size was calculated using standard random sampling equations

Outcome 2: More farmers and farm families are adopting technologies and practices to improve nutrition, food and feed safety, postharvest handling, and value addition

Output 2.1: *Improved technologies, innovations, practices, and habits to increase production and consumption of safe diverse and more nutritious food for farm families, especially by women and children, developed and disseminated in partnership with research and development partners*

Activity 2.1.2: *Increase the capacity of farm families, especially women, to produce and consume diverse and more nutritious food*

Sub-activity GH2121-19: Using the power of radio to promote women's empowerment for improved nutrition outcomes (Lead institution: UDS-SH)

This sub-activity is a follow up to the previous work conducted in 2018/2019. Activities were carried out with strong collaboration with the Ghana Health Service and the Ministry of Agriculture at the district and sub-district levels. The radio health/nutrition education consisted of evaluating a series of health and nutrition drama that are broadcast in local dialects over five radio stations in the intervention districts. The radio jingles/spots which were aired on five radio stations (Radio Upper West, Nabiina Community Radio, Zaa Radio, Radio Wa, and Radio Justice) focus on promoting key nutrition behaviors/practices. This evaluation compared nutrition and health knowledge, attitudes, and practices of mothers/caretaker who received radio health/nutrition education versus not receiving such education in comparison communities.

Exposure to radio listening: A greater proportion of respondents listened to radio (80.9%) and the popular radio stations respondents listened to included Zaa Radio and Simili Radio (Dalung) which reach out to the Savelugu and Tolon districts. Nabiina Radio is the sole radio station in the Kassena/Nankana District in Navrongo. Radio Wa and Tumpaani FM in the Upper West Region also have a good listenership.

Key infant and young child feeding (IYCF) messages heard on radio: Table 13 shows a comparison of the key IYCF messages listeners heard on radio in the past six months in the comparison and intervention communities. The proportion of respondents who heard specific messages was generally higher in the intervention than comparison communities. Agreement on "empowering women decision-making power" was however not different in the study communities. The message which listeners heard least was with regards to "Women need not ask the permission of other household members to buy items such as vegetables or fruits, clothing, etc."

Table 13. Key IYCF messages heard on radio in the past six months.

Nutrition/Health message	Number	Study groups		Test statistic
		Control no. (%)	Intervention no. (%)	
A. "Start complementary feeding at six months; not earlier, not later	408	126 (30.9)	282 (69.1)	Chi-squared (χ^2) = 39.8, $p < 0.001$
B. "Give your children a variety of foods for healthy growth"	414	125 (30.2)	289 (69.8)	$\chi^2 = 47.4$, $p < 0.001$
C. "Green leafy vegetables are rich in substances that help the body to make blood for children and adults"	419	123 (29.4)	296 (70.6)	$\chi^2 = 57.1$, $p < 0.001$
D. "To prevent anemia, give your children fish and meat frequently in sufficient amounts"	412	125 (30.3)	287 (69.7)	$\chi^2 = 45.5$, $p < 0.001$
E. "Add fats and oils to your children's food for strength and vitality"	400	123 (30.8)	277 (69.3)	$\chi^2 = 38.9$, $p < 0.001$
F. "Give porridge that is thick enough to stay on the spoon for better nutrition and growth"	409	124 (30.3)	285 (69.7)	$\chi^2 = 44.9$, $p < 0.001$
G. "Make foods thicker, mashed, or chopped fine as your baby gets older"	409	123 (30.1)	286 (69.9)	$\chi^2 = 47.0$, $p < 0.001$
H. "Always remember to wash your hands with soap and water before handling your child's food"	436	126 (28.9)	310 (71.1)	$\chi^2 = 68.9$, $p < 0.001$
I. "Keep your cooking utensils clean and safe from germs"	436	126 (28.9)	310 (71.1)	$\chi^2 = 68.9$, $p < 0.001$
J. Women need not ask the permission of other household members to buy items such as vegetables or fruits; clothing for yourself; medicines for yourself; personal supplies (soap, shampoo, dental paste, sanitary napkins, etc.)	321	127 (39.6)	194 (60.4)	$\chi^2 = 0.3$, $p = 0.6$

Impact of radio listening behavior on health/nutrition related attitude and practices

The difference-in-difference (DID) analysis was used to compare the changes over time in health and nutrition-related knowledge and practices in intervention and control communities as shown in Table 14. Controlling for covariates including mother's age, mother's education, time, and treatment versus control suggests radio listening behavior was significantly related to health/nutrition-related attitudes (HNRAs) score. The time × treatment group interaction analyses (i.e., difference-in-differences analyses) showed significant effects.

To get confidence intervals for the DID in mean Z-scores, OLS regression was run:
$Y = \alpha + \beta1\text{ (treatment)} + \beta2\text{ (time)} + \beta3\text{ (treatment}*\text{time)}$

The unstandardized regression coefficient (β3) estimates the DIDs and it was 1.995 for HNRAs score, p = 0.001. This tells us whether the expected mean change in outcome from before to after was different in the two groups. The coefficient of the treatment (intervention) variable, β1, is the estimated mean difference in Y between the treatment and control groups prior to the intervention: From the results presented in Table 14, the mean difference in HNRAs was not significant at baseline. β2, which is the coefficient for survey time, is the expected mean change in outcome from before to after the onset of the intervention among the control group. It reflects the true effect of the passage of time in the absence of the actual intervention (that is, the counterfactual).

Compared to women who had no formal education, women of highest educational level (at least senior high school) had a HNRAs score which was significantly higher by 0.642. Compared to respondents who did not listen to radio, those who listened to radio had a mean HNRAs score which was significantly higher by 2.535 units. Compared to respondents who listened to radio once a week, those who listened every day in a week had a mean HNRAs score which was significantly higher by 1.852 units. A one unit increase in mother's age corresponded to a 0.057 increase in HNRAs score.

Table 14. Pre- and post-test differences by treatment group and the effect of the intervention on health and nutrition-related attitudes.

Model	Unstandardized coefficients		Standardized coefficients	Sig.	95.0% confidence interval for β	
	B	Std. error	Beta		Lower bound	Upper bound
(Constant)	17.533	1.742		0.000	14.115	20.950
Time of survey (Endline)	-2.896	1.044	-0.242	0.006	-4.944	-0.847
Treatment/intervention	-0.493	0.962	-0.041	0.608	-2.381	1.394
Interaction (Time × treatment)	1.995	0.610	0.358	0.001	0.798	3.192
High mother's educational level	0.642	0.239	0.066	0.007	0.173	1.110
Age of mother	0.057	0.024	0.059	0.017	0.010	0.104
Listen to radio	2.535	0.563	0.167	<0.001	1.429	3.640
Frequency of radio listening (everyday)	1.852	0.192	0.323	<0.001	1.475	2.229

Conclusion

In conclusion, the data provides evidence that health and nutrition education using mass media in the form of radio drama significantly and positively increased health/nutrition-related knowledge and positive attitude towards health seeking behaviors but had little effect on the nutritional status of children. This is important information for health policy makers in both government and nongovernmental organizations in identifying the possible effective interventions that may move people from the knowledge levels to positive practices for the improved health and nutrition of deprived rural communities.

Sub-activity GH2122-19: Improving Child and Maternal Nutrition through Home Container Vegetable Gardening (Lead institution: UDS-SH)

Training of trainers (ToT) on home container vegetable gardening held for 15 district agricultural field extension workers. Training of community interest groups (e.g., women's groups) has been completed and training was held for 180 farmers. Sample pictures of the training and community sack garden implementation are presented in Figure 26.

Training of trainers (TOT) in Tamale (learning)

Training of trainers (TOT) container vegetable gardening

Demonstration session during TOT on home container vegetable gardening in Tamale

Demonstration session during TOT on home container vegetable gardening in Tamale

Training in sack gardening in Zanko, Wa West

Model sack garden at Zanko, Wa West

Figure 26. Photo grid for field activities on sack gardening in Ghana. Photo credit: Jean Baptiste Tignegre/WorldVeg.

Sub-activity GH2123-19: Engaging Men to Increase Support for Optimal Child Feeding Practices Using Care Group Approach/Model (Lead institution: UDS-SH)

Having been in operation for six months, the Care Group members, were officially inaugurated to encourage community participation and support for the Care Group volunteers. The official inauguration was held in the Africa RISING intervention communities in the Northern, Upper East, and Upper West regions of Ghana from 8 to 18 January 2020. The uniqueness of the Care Group Model membership is the inclusion of men to help increase support for optimal child feeding practices. Sample photos are presented in Figure 27.

Durbar and nutrition competition day of Care Group members in Tingoli community, Tolon District.

Typical composition of Care Group members in Tingoli, Tolon District.

Typical composition of Care Group members in Tingoli, Tolon District.

Inauguration of Care Group members at Kpallung Community in Savelugu District.

Nutrition community durbar in Passe, Wa West District.

Inauguration of Care Group members at a community durbar in Nator-Duori- Nadowli District.

Figure 27. Photo grid for field activities on the Care Group model. Photo credit: Mahama Saaka/IDS.

The objective of the health/nutrition education radio was to compare nutrition and health knowledge, attitudes, and practices of mothers/caretaker who received radio health/nutrition education versus not receiving such education in comparison communities.

The main finding was that mass media radio health and nutrition education via drama can effectively increase mothers' nutrition knowledge and positive attitude towards health-seeking behaviors but had little effect on the nutritional status of children. Furthermore, maternal poor nutrition knowledge was one of the factors for poor dietary practice.

Problems/challenges and measures taken: Addressing the problem of malnutrition goes beyond lack of access to adequate food availability. There are some barriers to the attainment of optimal nutrition, one of them being the involvement of men in household chores like childcare, fetching water, and cooking food. There was varied agreement with regards to the role of men in reducing women's workload in the household and whether "men should be involved in household chores." This challenge is being worked on using appropriate nutrition behavior change communication approaches such as the involvement of men in nutrition education using the care group model at the community level.

Lessons learned: Mass media radio health and nutrition education via drama can effectively increase mothers' nutrition knowledge and positive attitude towards health-seeking behaviors.

Success stories: Given the high workload of health personnel, mass media in the form of radio broadcasts can be used as an alternate platform to deliver appropriate health and nutrition messages simultaneously to a large number of targeted audiences.

Output 2.2: *Postharvest technologies and practices to provide options for the food, and feed sectors are tested and disseminated to farmers, through researchers, extension staff, and development partners*

Activity 2.2.1: *Introduce, evaluate, adapt, and disseminate existing postharvest technologies and practices*

Sub-activity GH2211-19: Evaluate the threshing efficiency of different maize shellers with regards to grain quality characteristics as influenced by different varieties and harvest timing (Lead institution: SARI)

This sub-activity is complementary to ongoing work being conducted by IITA in Sub-activity 2212 entitled "Monitoring group dynamics among users of small-scale maize shelling machines in Northern Ghana."

This study (sub-activity GH2211-19) examined the emerging role of maize threshing machines in northern Ghana and identified options to address their accessibility, adoption, and operational efficiency. The study was conducted in four districts in the Northern Region of Ghana. The field work involved key informant interviews and field measurements conducted between October 2019 and February 2020. The effect of threshing techniques on efficiency characteristics (damaged grain, whole grain, and overall physical purity) was assessed. This study suggests an urgent need to upgrade postharvest operations to accommodate emerging developments and dynamics of agricultural intensification where the use of human labor has become costly and less efficient. This study examined (1) the emerging role of mechanized harvesting and threshing operations in northern Ghana and options to address their availability, cost, adoption, and operational efficiencies, and (2) threshing performance characteristics of different maize threshers and socioeconomic benefits to farmers.

Scope of study: The study was conducted in four districts: Binduri and Kassena Nankane East Municipal (KNEM) in the Upper East Region and Savelegu and Karaga districts in the Northern Region. Binduri and Karaga Districts were chosen due to the relatively large proportion of farmers engaged in maize production. The KNEM and Savelegu districts have been involved in the Africa RISING Project implemented by IITA, Ghana. Through this partnership, the beneficiary communities were supported with semi-mechanized diesel-powered maize shelling machines (R170A Max. engine power: 4.95Ps, 12 hr rated power 4.5Ps, declared speed: 2600 r/min, average weight 43 kg) on work-and-pay basis.

Survey tools: The field work involved key informant interviews and field measurements which lasted from October 2019 to February 2020. This period corresponded to the peak harvesting of cereals in northern Ghana. Purposive sampling targeting farmers who essentially had employed the services of a maize threshing machine this year was adopted. The second level of randomization involved accidental interviews of farmers who were shelling their maize at the spot. An interview guide was developed to generate information on production operations, farm size, yield, postharvest operations, labor requirement, factors influencing the use of shelling machines, and associated challenges.

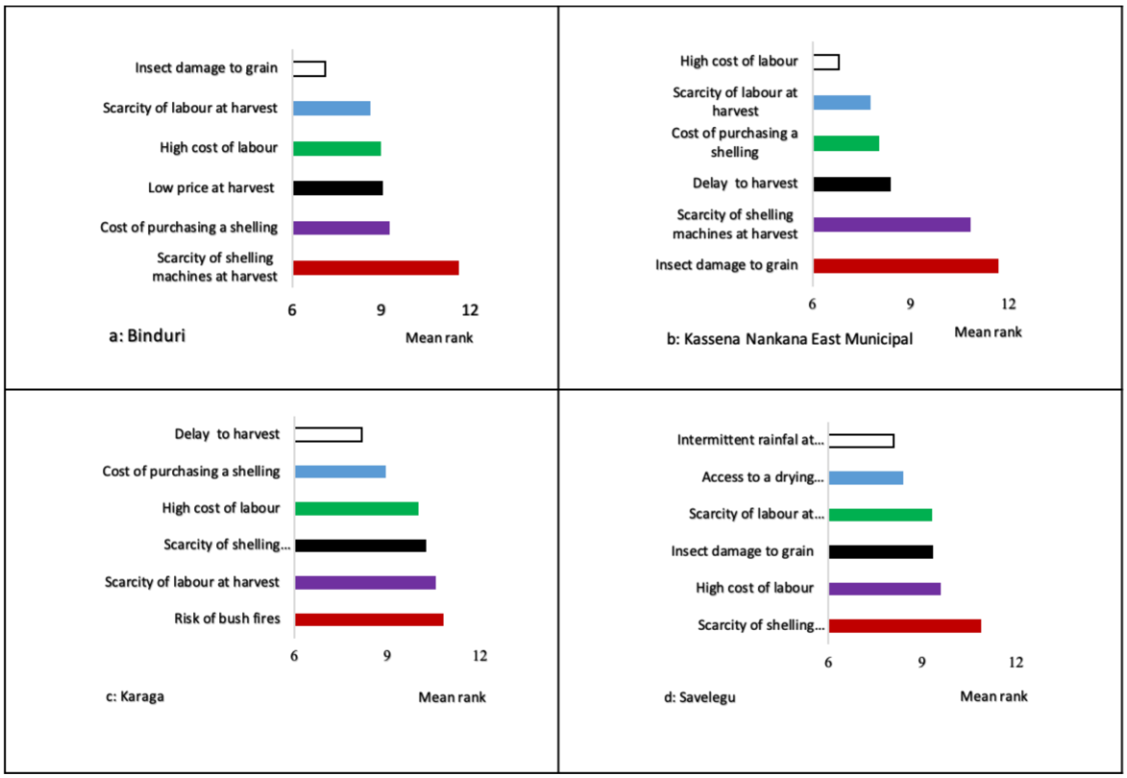
Labor requirement and cost: Primary data was collected from randomly selected maize farmers on farm size, production capacity, and labor used for harvesting, gathering, dehusking, shelling, cleaning, and bagging. The technologies tested were mechanized threshing, semi-mechanized threshing, and manual threshing. Each technology was associated with the following postharvest operations: harvesting, gathering, dehusking, shelling, and bagging. Man-daysis the time in days (~6–8 hours) required for one person to complete a task. The total man-days for each threshing technique is the sum of the man-days of all associated postharvest operations. The total cost of a particular operation is a product of the total man-days and the wage rate of the postharvest operation at that specific location.

Community demonstrations and trainings: Participatory demonstration and training sessions are yet be conducted in AR communities. Training sessions will comprise two hours of technical information and two hours of hands-on operation of the machines. Training messages will be focused on benefits of using grain shellers, identifying appropriate harvest indices, determination of grain moisture, shelling performance of machine, grain cleaning, grain protection options, and best grain storage practices. The growers will be linked to implement suppliers and manufacturers.

Results and discussion: Some socio-demographic characteristics such as gender, age, educational level, and average farm size were evaluated (tabular and graphical results are not presented herein, however, the gender distribution was 35.6% female and 64.4% male). The majority of the respondents (40%) had no formal education, only 28.9% and 24.4% had basic and college education, respectively. Maize production commenced in late June and peaked in early to mid-July across the districts studied. Overall, 77.8% of the respondents were smallholders with farm size of about 0.5-5 ha. Maize production in KNEM, Binduri and Savelegu districts was carried out at smallholder levels (0.5–5 ha) when compared to Karaga (2–38 ha).

Also, maize yield was lowest in KNEM (0.79 MT/ha), and highest in Karaga (1.26 MT/ha) where huge fertile arable lands still exist.

In terms of demand for threshing services, it was observed that these were highest in Karaga District, where large acreages of maize (2–38 ha) existed. The demand for multi-crop threshers (rice, maize, and soybean) was high among the well-endowed farmers. Although the cost of such machines may exceed their purchasing power, the farmers identified the work-and-pay option of ownership as a sustainable solution if government and other partners were ready to support. We offer further insights about the district level perception and ranking of critical constraints affecting shelling operations in Figure 28.



* Where rank 1 is the most constraining factor and in similar order

Figure 28. District level perception and ranking of critical constraints affecting shelling operations.

Outcome 3: Farmers and other value chain actors have greater and equitable access to production assets and markets (input and output) through enabling institutions and policies

Output 3.1: *Improved policies and institutional arrangements to increase participation of farm families, especially women and youth in the output and input markets and decision-making are developed*

Activity 3.1.1: *Identify constraints to and opportunities for improving access to the output and input markets by women and youth in the target area*

Sub-activity GH 3111-1901: Strengthen the technical, managerial, and organizational capacities of the major actors in small ruminants value chain through existent institutional structures such as farmer-based organizations (FBOs), district assemblies (DA), community based organizations (CBOs), traders associations, and transports and input dealers association (Lead institution: CSIR- ARI)

During the last quarter of 2019 (mid-end of November), a research team from CSIR-ARI visited Ouagadougou, Burkina Faso to learn about the operations of the small ruminant value chain. During the visit, the team visited INERA (Institut de l'Environnement et Recherches Agricoles), a USAID Project on Resilience and Economic Growth in the Sahel (REGIS-AG), the Department of Animal Production at the Ministry of Animal Resources and Fishery, and the Tanghin small ruminant market.

From the baseline study of the small ruminant value chain in the intervention communities in Northern, Upper East, and Upper West regions, the constraints faced by the value chain actors included animal diseases, feed scarcity, theft, and harassment by police (Table 15). The prioritization of interventions to strengthen the small ruminant value chain in the intervention communities essentially centered around animal health, feed, housing, and institutional support (Tables 16 & 17). In relation to the highlight of SI indicators and their defining metrics for the work we did, the data collected on efficient feed utilization through improved feed troughs is related to the productivity, environmental, economic, social, and human domains. The indicator for the productivity domain is input use efficiency (quantity of feed saved from waste); for the environmental domain it is manure quantity collected and manure quality; for the economic domain the indicator is profitability (cost and benefit of improved feed troughs); for the social domain the indicator is gender equity (time spent on feeding the animals by gender); and for human domain the indicator is capacity to experiment (number of modifications made to the feed troughs at household level). The detailed tabular data and results will be shared in the next reporting cycle.

Results on strengthening the small ruminant value chain in Northern Ghana are presented below (Table 14).

Table 15. Challenges that were identified concerning the small ruminant value chain in the study areas.

No.	Challenge	Abbreviation
1	Poor health of animals	Health/H'lth
2	Getting feed in the farming season for animals	Feed
3	Poor quality animals	Anl. q
4	Harassment by police	Pol
5	Theft	Thef
6	Producers not organized into an association	Produ/Pro
7	Nobody seems to be in charge of the entire value chain	I/C
8	Market does not have a wall or fence	Wall/Wa
9	There are no shelters in some markets	Shelt/Shlt
10	Poor small ruminant houses	SR hse/hse
11	Butchers slaughtering mostly female animals	F. anls/F. an
12	Low revenue generation	Reven/Rev
13	Poor access to financial institutions	Financ/Fin
14	Butchers defaulting in payment	B. df
15	High water bill for butchers	W. bill/W. bl
16	High price of animals	H. pric/H. pr

Table 16. Prioritization of challenges in Navrongo.

No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
		Health	Feed	Anl q	Police	Theft	Pro	I/C	Wa	Shelt	Hse	F. an	Rev	Fin	B.df	W. bl	H. pr	Total
1	Health		feed	H’lth	H’lth	H’lth	H’lth	I/C	H’lth	H’lth	Hse	F.an	H’lth	H’lth	H’lth	H’lth	H’lth	11
2	Feed			Feed	Feed	Feed	Feed	I/C	Feed	Feed	Feed	F.an	Feed	Fin	Feed	Feed	Feed	12
3	Animal quality				Anl. q	Anl. q	Pro	I/C	Anl. q	Anl. q	Hse	F. an	Anl. q	Anl. q	Anl. q	Anl. q	Anl. q	9
4	Police					Theft	Pro	I/C	Wa	Shelt	Hse	F.an	Rev	Fin	Pol	Pol	H.pr	2
5	Theft						Pro	I/C	Wa	Shelt	Hse	F.an	Thef	Thef	Thef	Thef	Thef	6
6	Produ							I/C	Pro	Pro	Pro	F. an	Pro	Pro	Pro	Pro	Pro	10
7	I/C								I/C	I/C	I/C	I/C	I/C	I/C	I/C	I/C	I/C	16
8	Wall									Shelt	Hse	F.an	wall	wall	wall	Wall	H.pr	6
9	Shelter										Hse	F.an	shlt	shlt	shlt	shlt	H.pr	7
10	SR hse											Hse	Hse	Hse	Hse	Hse	Hse	12
11	F. anls												F.an	F.an	F.an	F.an	F.an	13
12	Reven													Fin	B.df	Rev	H.pr	2
13	Financ														B.df	Fin	H.pr	4
14	B. dfalt															B.df	H.pr	3
15	W. bill																H.pr	0
16	H. pric																	7

Table 17. Prioritization of challenges in Wa.

No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
		Health	Feed	Anl q	Police	Theft	Pro	I/C	Wa	Shelt	Hse	F. an	Rev	Fin	B.df	W. bl	H. pr	Total
1	Health		hlth	hlth	hlth	hlth	hlth	I/C	hlth	hlth	Hse	F.an	hlth	Hlth	Hlth	Hlth	Hlth	12
2	Feed			Aniq	feed	Thft	pro	i/c	feed	feed	Hse	feed	feed	Fin	feed	feed	H.pr	7
3	Animal quality				Ani.q	Ani.q	Ani. q	Ani. q	Ani.q	Ani.q	Aniq	Ani.q	Ani.q	Ani.q	Aniq	Ani.q	Ani.q	14
4	Police					Thft	Pro	I/C	Pol	Shltr	Hse	F.an	Rev	Fin	but	Pol	Pol	3
5	Theft						Pro	Thft	Thft	Shltr	Hse	Thft	Thft	Thft	Thft	W.bl	Thft	9
6	Produ							I/C	Pro	Pro	Hse	Pro	Pro	Pro	Pro	Pro	Pro	11
7	I/C								I/C	I/C	Hse	I/C	I/C	Fin	I/C	I/C	H.pr	10
8	Wall									Shlt	Hse	F.an	Wal	Fin	wal	wal	H.Pr	3
9	Shelter										Hse	F.an	Shlt	Fin	But	Shltr	H.Pr	5
10	SR hse											Hse	Hse	Hse	Hse	Hse	Hse	14
11	F. anls												F.an	F.an	F.an	F.an	H.Pr	8
12	Rev													Fin	But	W.bl	H.Pr	1
13	Financ														Fin	Fin	H.Pr	8
14	B. dfalt															W.bl	H.Pr	3
15	W. bill																H.Pr	3
16	H. pric																	9

Strengthening the technical capacities of small ruminant value chain actors including men, women, and youth will impact positively on small ruminant productivity. It is envisaged that as a result of the training, some farmers might be formulating their own feeds as well as establishing model small ruminant houses. The handbook under preparation would also provide a guide in the effort towards strengthening the small ruminant value chain in Ghana.

Capacity building
Training on the small ruminant value chain took place in Navrongo, Upper East region on 17 March 2020. The training topic was focused on "How to increase the supply of male small ruminants to the market". It was attended by 21 participants (2 females and 19 males). Male ruminants are in very high demand in the region due to consumer preferences for male ruminants.

The main conclusions are as follows:

- The construction of model small ruminant houses in intervention communities requires collective action by community small ruminant owners.
- The construction of model small ruminant houses in intervention communities has the potential of increasing manure storage and application within farmer fields for increasing soil fertility and crop yield improvement.
- Better housing of animals has the potential of reducing animal thefts thereby saving more animals to improve the food and nutrition security of farmers.
- Upgrading of small ruminants with the superior male breeds requires collective action by small ruminant farmers in beneficiary communities.

A number of challenges were encountered during this reporting period; there was poor participation of women in the small ruminant value chain engagements as most of the actors were men, particularly the traders. Even where women own small ruminants, culturally the animals are the property of the husbands. To be a member of the innovation platform, preference is given to actors who are literate. Therefore, it may be difficult to find an equal number of women who are literate like their male counterparts and are engaged in the small ruminant value chain. The approach this project adopted was to target early adopters, committed farmers, positive deviants, literate farmers, and "not-so-poor" farmers to spur growth that can then benefit the poor, particularly through multiplier effects generated by the sector development. The incidence of COVID-19 made it impossible for the main project implementers to visit Wa West project communities to deliver the breeding males and supervise the construction of the model houses. These responsibilities were transferred to Wa West Livestock Officer to implement on behalf of the team and keep the communication channel open for exchange of information. The outcome of this initiative will be followed up and reported in the next reporting cycle.

Our team interacted with the USAID project on Resilience and Economic Growth in the Sahel (REGIS-AG) in Burkina Faso for lesson learning on interventions to strengthen the small ruminant value chain. The lessons learned on strengthening small ruminant value chain is that development of the small ruminant value chain in Ghana requires active involvement and coordination by institutions such as the Ministry of Food and Agriculture. The Ministry should have a national directorate of livestock value chain development.

Output 3.2. *Options to increase access to production assets and increase participation in decision-making by women, youth, and other vulnerable groups.*

Activity 3.2.1: *Identify constraints to, and opportunities for increasing women and youth access to production assets in the target area.*

Sub-activity GH3211-19: Evaluate risk and vulnerability as well as resilience within maize-cowpea living mulch systems in relation to smallholder farmers' livelihoods.

This sub-activity is a synthesis endeavor that links with sub-activity GH1212-19 which assesses the impact of soil and water conservation interventions. This sub-activity complements the former in that it evaluates the risk and vulnerability as well as resilience within the maize-cowpea living mulch systems in relation to smallholder farmers' livelihoods. This allows us to explore risk and resilience issues within maize-cowpea living mulch systems and how these can better inform us on options towards reducing vulnerabilities of smallholder farmers while increasing resilience and livelihood opportunities. The work that was conducted for this sub-activity went beyond cowpea-living mulch and encompassed other interventions through a region-wide survey that had 545 respondents. Work from this study has been synthesized into a manuscript that is going through an internal evaluation process.

To develop effective, measurable resilience-building strategies, we considered the complex interactions that exist between risks, people, and the socio-ecological systems in which they live. These interactions occur at various spatial and temporal scales and are inherently dynamic. Thus, when shocks hit a system such as farming systems for Africa RISING farmers, they do not occur in isolation; rather, they interact with multiple factors that can compound their impact and provoke downstream effects. Understanding socio-ecological systems, for instance, requires understanding how people think, engage with one another and their environment, and react to and affect changes from the local level to the community, regional, and national level. For this sub-activity we principally considered the local to community levels using both biophysical and ecological modeling, focused group discussions, and economic tools as well as the SIAF to allow for a systems approach. Table 18 exemplifies how the SIAF data was collected and Figure 29 illustrates how the SIAF domains relate to the cowpea living mulch technology before and after the intervention.

Table 18. Sustainable intensification indicators for Sub-activity GH3211-19.

Domain	Indicator	Metrics and scale of measurement	Methods/Approaches taken including duration	Before intervention	After intervention
Productivity	Crop productivity	Yield (kg/ha/season) at the field/plot level	Agronomic trials (see GH111-19) for 2017, 2018, and 2019	Maize: 1.2 kg/ha/season (plot level)	Maize 3.2 kg/ha/season (plot level)
				Cowpea: 0.4 kg/ha/season (plot level)	Cowpea: 1.7 kg/ha/season (plot level)
Environmental	Erosion	Soil retention (MT/ha/season) at the plot level	- Field measurements - Modeling with SWAT	0.2 MT/ha/season	1.2 MT/ha/season
	Soil water storage	Seasonal soil moisture storage mm/m	Environmental research (See GH 1212-19)	10 mm/m	45 mm/m
Economic	Profitability*	Net income (US$/kg/ha/season) at the plot level	Econometric analysis based on productivity data (combined both maize and cowpea productivity data)	177,600 kg/ha/season	602,800 kg/ha/season
	Input use intensity	Input per ha at the plot level	Econometric analysis based on environmental data	6 kg/ha/season	75 kg/ha/season
Social	Gender equity	Capacity: Access to information (household) percentage (%)	Surveys and FGDs using direct engagements and electronic tools (Insyt and Kobo Collect)	22%	65%
	Collective action	Participation in a collective action group (% Household)		35%	80%
Human	Capacity to experiment	Number of new practices being tested (household level)	Using ICT and GIS tools (see GH4121-19	2	7

		% of farmers experimenting (community level)	Surveys and FGDs	20%	74%

The work conducted largely followed USAID's resilience guidance notes[14] with a few modifications and entailed four steps:

- Step 1: Planning and design in order to determine the purpose (on how will this analysis be used, by whom), scope, and scale of the assessment as well as the level of effort while taking stock of existing data, identifying knowledge gaps, and creating a research plan to respond to key questions on resilience capacities and risks. This was followed by:
- Step 2: Data collection which entailed qualitative and quantitative data from primary and/or secondary sources that helped to fill knowledge gaps identified in Step 1.
- Step 3: Analyzed and interpreted data to answer key questions as determined in Step 1.
- Step 4: Strategic planning. Translated findings into appropriate outputs around resilience-building programmatic strategies. To measure absorptive, adaptive, and transformative capacities of resilience at the household and community scales, we linked aspects of resilience to the SIAF at the aforementioned scales.

The study reveals that resilience is dynamic and can be estimated with an index using a mixed methods approach. Factoring in algorithms to set clear boundaries of where a household falls in terms of resilience index may be novel for future research.

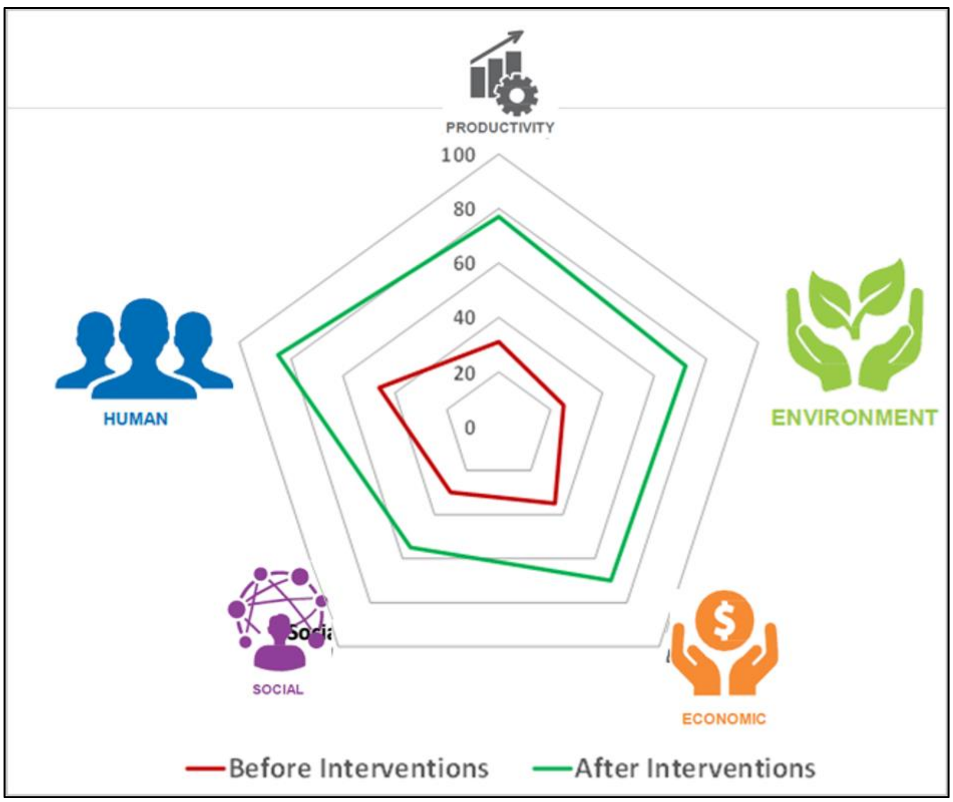
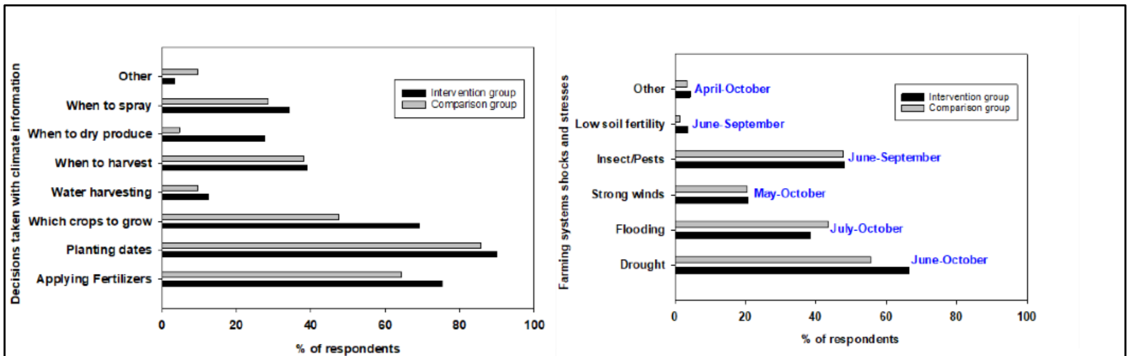


Figure 29. Representation of the five domains in relation to resilience within maize-cowpea systems.

[14] USAID Resilience Measurement Practical Guidance Note Series

Factors such as participation in a given intervention such as Africa RISING interventions, age, sex, asset ownership, information access, decision-support, and management practices play a critical role in determining the resilience of a given household. These options may feature less often in mainstream literature but seem to be fundamental in resilience construction. We find that economic status such as per-capita expenditure and geographical location of a household may put it at a disadvantage as in the case of Upper West region. However, it is evident that recall of shocks experienced suffer from recall bias because respondents recall the most recent one they experienced without consideration of some shocks with long-term effect on household adaptive capacity. Furthermore, immediate action taken after shock, does not necessarily translate into resilience within a household. This means that long-term planning into the future supported by frequent information and decision, may be an option in mitigating climatic shocks.



Changes that respondents made in their farm enterprises as a result of receiving climate information (no. intervention group = 275; no. comparison group = 237).

Farming systems shocks and stresses to farm enterprises with comparison of intervention group and comparison group (no. intervention group = 275; no. comparison group = 237). The months in blue indicate the duration these stresses were most pronounced based on respondents.

Figure 30. Illustration of decisions taken with SI information (left) and the nature of shocks and stresses experienced.

The principal policy challenge may be unlocking a given household's potential to harness what it has to be more resilient to shocks. Strengthening a households' knowledge of available coping strategies and categorizing them to avoid detrimental ones may be an avenue to pursue. Common means of supporting resilience may include integrating indigenous knowledge and centuries-old coping strategies into future intervention theories of change. This study indicates that individuals supported by the Africa RISING project were more resilient. Additionally, when such knowledge is integrated, households may build on lessons learned, even after the project ends, to improve their coping strategies and for sustainability. Among strategies to develop more resilient households is observing months within which such shocks are frequent, for example, June through October, as was this case. During such periods, vulnerability increases and migration may be an option. Hedging such adversaries may be of interest to public authorities or decision makers who may integrate early warning systems or develop training manuals on adaptation and resilience. One fallacy may be perception of risks as acceptable once a "do nothing when disaster strikes" strategy is adapted by some households. These may thwart the government's efforts to mitigate or respond at appropriate times when it is still safe. Policy/decision makers who have implemented coping strategies may acknowledge that it is not realistic to expect households to keep rising whenever they face shocks. Some households may go under and never recover. Our findings, therefore, add to the literature on resilience by fronting novel ways of constructing the resilience index and applying algorithms to set boundaries for households while using the SIAF in a novel way to assess how sustainable the options are. Further details are provided in the draft manuscript.

Complementary activities for this sub-activity included a study of systems modeling around the cowpea living mulch (Fig. 31).

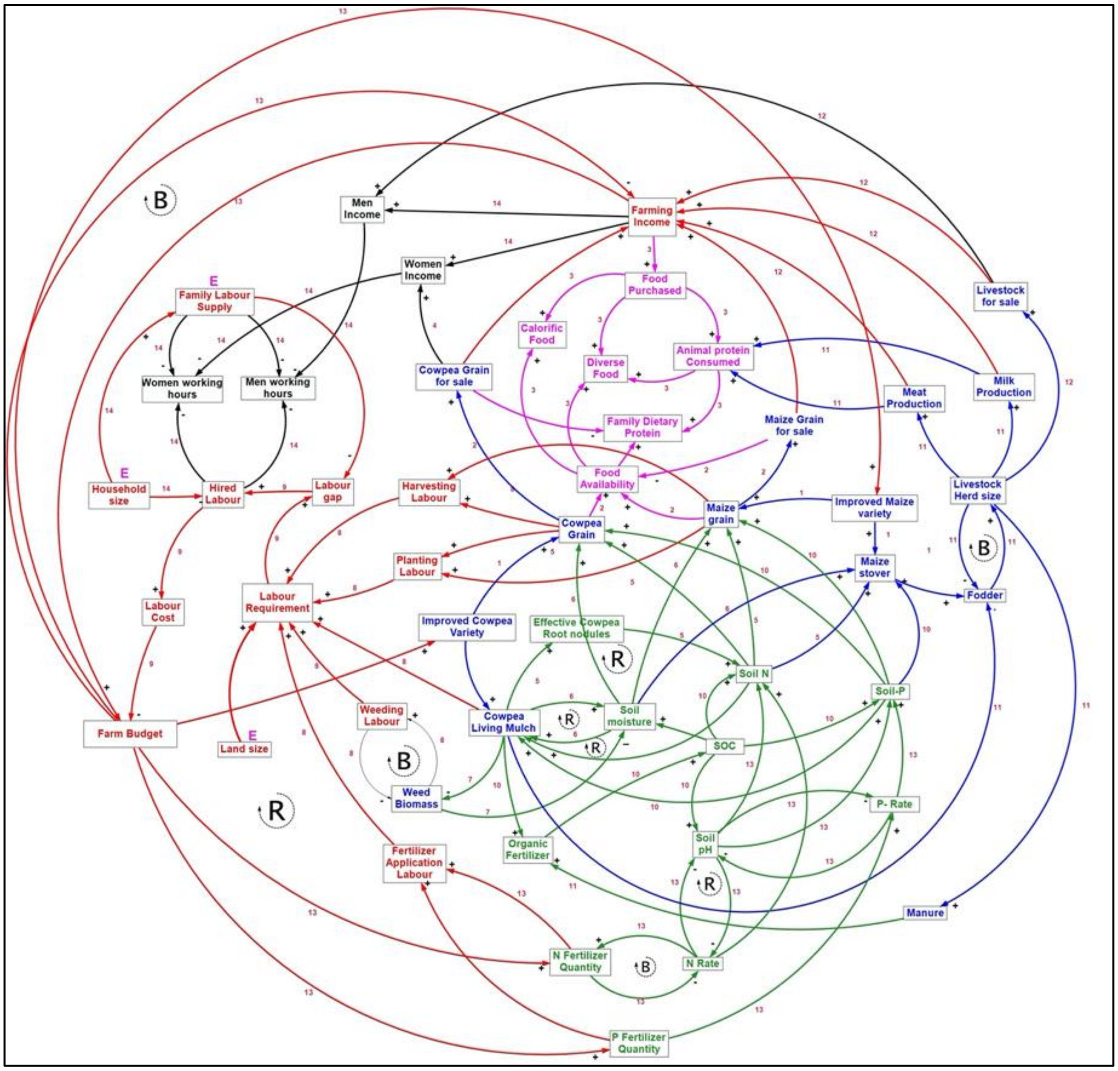


Figure 31. The causal loop diagram for a cowpea living mulch (CPLM) system in Northern Ghana. The "R" and "B" represent the reinforcing (positive) and balancing feedback loops in the system, respectively. Letter (E) above some variables indicates that they are exogenous factors. The different colors represent the five sustainable intensification domains: red = economic, pink = human, blue= productivity, light green = environment, and black = social.

The feedback loops in the CPLM intercropping system in farming systems of Northern Ghana are presented in Figure 31. Family labor supply, land size, and household size are considered as exogenous factors in the system, therefore the letter E above the name of variables in the CLD (Fig. 31). These are conditions that are outside the CPLM system although they can impact the system either positively or negatively. In the CLD, different colors are used to categorize the five sustainable intensification domains: red = economic, pink = human, blue= productivity, light green = environment, black = social. Moreover, the reinforcing (positive) and balancing (negative) feedback loops in the system were identified using letter "R" and "B," respectively (Fig. 31). Reinforcing loops represent escalation between variables, e.g., an increase in soil moisture results in an increase in cowpea biomass which in turn accentuates soil moisture storage due to reduced soil evaporation. The balancing loops describe a relationship where an increase in stock of variable triggers a feedback mechanism that cause a decrease of the initial stock. For example, increased fodder results in increased livestock herd size, but the higher herd size results in less fodder stock. Please note that not all "R" and "B" loops are identified in Figure 31; it is expected that more will be identified during further consultative processes.

Outcome 4: Effective partnerships are built with farmers, local communities, and research and development partners in the private and public sectors to ensure delivery and uptake at scale of SI, technologies, innovations, and practices.

Output 4.1: *Alliances and effective partnerships developed between farmers, local communities, and research and development agents in the public and private sectors to enable the release, dissemination, and adoption of proven technologies and practices to scale.*

Activity 4.1.1: *Conduct cost-benefit and gender analysis coupled with other socioeconomic analyses to identify and quantify adoption constraints and opportunities for different farmer contexts.*

Sub-activity GH4111-19: Conduct simulation and other socioeconomic analyses of selected SI technologies/practices for different farmer contexts, to have a better understanding of the adoption potential of these proven technologies and opportunities for scaling up (Lead institution: STEPRI).

The main tasks of the sub-activity were to: (1) investigate the potential net gains/net losses per farm returns, per capita income, and poverty rates for smallholder farms in Northern Ghana with and without the adaptation of SI practices/technologies; (2) determine the potential rates of adoption of technologies being practiced among smallholder farmers (livestock,mainly small ruminants; maize; and cowpeas) in Upper East, Upper West, and Northern regions of Ghana; (3) analyze the potential for uptake of SI technologies—which types of farmers are likely to use them and with what expected outcomes? The planned methodology followed a mixed method approach and both household survey and secondary data generated by technology developers constitute the main data sources. A total of 420 farm household surveys (female; male) were conducted from both Africa RISING and non-Africa RISING communities in the Upper West, Upper East, and Northern regions of Ghana, and insights generated on the adoption potentials of the various technologies considered. The data will be cleaned and econometric analysis performed using the Trade-off Analysis Minimum Data Model (TOA-MD) proposed. The data will also be uploaded in data verse.

The team developed a conceptual framework and empirical methodologies. The team will also conduct simulation and other socioeconomic analyses of selected SI technologies/practices for different farmer contexts, to have a better understanding of the adoption potential of these proven technologies and opportunities for scaling up. During the reporting period, the team reviewed several policy documents and articles (18 in total) to draw some insights on the sub-activity. The empirical literature review on technology adoption and climate-smart agriculture revealed that (i) a large-scale intensification program with externally prescribed quotas for planting export crops[15] (Clay and King 2018) can exacerbate existing risks and introduce new risks in the form of crops ill-suited for the region or for particular parcels or farming systems and (ii) the importance of the network structure on diffusion dynamics[16]. Network measures employed to characterize the Innovation Platforms (IPs) were the degree of centrality, closeness, average reciprocal distance, local clustering coefficient, and eigenvector. Previously, Rai and Robinson (2015)[17] presented a methodological framework on technology adoption based on agent-based models to show that agents' adoption decisions are jointly determined by both attitudinal and control beliefs (education, retirement status, race, political affiliation, family composition).

Sample size, sampling technique, and data collection procedure: A total sample size of 420 farmers was taken from the three Northern regions (Upper West, Upper East, and Northern regions) for the household survey. This comprised about 250 Africa RISING beneficiaries and 170 non-Africa RISING beneficiaries. In all, 13 communities were covered across six districts. Stratified and systematic sampling techniques were followed in selecting the respondents. For the stratified sampling, the population of the communities was divided into subgroups of two strata: Africa RISING project communities and non-Africa RISING project communities.

Synthesis: Use the SI indicator results to illustrate how outputs under the four outcomes are defining your innovation/technology. This research is focusing on the adoption of selected validated technologies by farmers on both crops and livestock under the Africa RISING project for potential scale-up. These selected technologies cover a wide range of issues on productivity, economic, environment, social, and human likely to affect the adoption behavior and decisions of farmers. The expected insights will be useful in discussing how improvements in farmer adoption can best be attained under the Africa RISING program and how meaningful scale-up could be achieved for greater sustainability and integration.

Section D. Partnership/linkages with other projects: CSIR-STEPRI collaborates with the Centre for Agriculture and Bioscience International (CABI) and leads the learning alliance and knowledge sharing component of the Sustainable Agricultural Intensification Research and Learning in Africa (SAIRLA) Program in Ghana. This activity is also directly linked to two other sub-activities being implemented under the Africa RISING program as it draws on the crops/productivity work being done by IITA (GH1111-19) and the crop/livestock activities being implemented by ILRI and ARI (Ayantunde and Salifu). The findings will therefore enrich policy discussions on technology adoption and generate more support from policymakers.

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[15] Clay, N. & King, B. (2018). Smallholders' uneven capacities to adapt to climate change amid Africa's 'green revolution': Case study of Rwanda's crop intensification programme. World Development, 116, 1-14.
[16] Barbuto, A., Lapolito, A. & Santeramo, F. G. (2019). Improving diffusion in agriculture: An agent-based model to find the predictors for efficient early adopters. Agricultural and Food Economics, 7 (1), 1-12.
[17] Rai, V. & Robinson, S. A (2015). Agent based modelling of energy technology adoption: empirical integration of social, behavioural, economic and environmental factors. Environmental Modelling and Software, 70, 163-177.

<u>Sub-activity MA4111-19:</u> Determine farmers' preferences of technology attributes in cereal-legume systems of southern Mali (Lead institution: ICRISAT).

The study focuses on identifying important traits associated with sorghum technologies as perceived by farmers in southern Mali. In addition, differences in the technology preferences among farmers with respect to gender and other farmer technologies are assessed. The study uses two types of data including household survey and focus group discussion (FGD). The FGD was completed in Bougouni and Koutiala districts. The discussion groups were composed of farmers producing sorghum and practicing intercropping sorghum and legumes such as groundnut and cowpea. Discussions were held for 45 min to 60 min per group and each FGD comprised 7 to 10 farmers. A total of 18 FGDs were undertaken with two FGDs per village (one men group and one women group). The questionnaire used for the FGD incorporated six main issues including: (i) crop production and productivity, (ii) costs and benefits related to the crop production, (iii) human nutrition, (iv) knowledge and control over crop production, (v) water and soil conservation, and (vi) farmer's preferences about sorghum technologies. Data analysis is ongoing. Results of the FGD will guide the development of survey questions and individual farmer surveys which will be conducted in April 2020.

<u>Sub-activity GH4112-19:</u> Evaluate the impact of SI practices on household welfare, poverty, perceived shock, the environment, and food and nutrition security in Northern Ghana (Lead Institution: IITA)

This is a new activity leading to a PhD award with WUR and was conducted between August 2019 and March 2020. On the overall, the field work was insightful and conducted successfully with ongoing analyses of field research.

Following are key highlights of the activities:

- IITA supported the entire process by providing a vehicle for the field survey in each region.
- Recruited and trained enumerators for the three northern regions (Northern region: 5–9 August, Upper West region: 13–19 August, and Upper West region: 24–29 August) for the field survey.
- In sum, seven enumerators (5 males and 2 females) were recruited and trained in the Northern Region; five enumerators (4 males; 1 female) were trained in the Upper West region, and five enumerators were signed up and trained in the Upper East region (3 males and 2 females).
- Data collection and monitoring were done using Computer Assisted Personal Interviews (CAPI), which were developed before the data collection.
- Sample size was revised from 530 households to 700 households to ensure representativeness.
- There were surveys for 50 communities conducted across the three northern regions of Ghana.
- During this period, there were regular visits and monitoring of activities for the enumerators across the three regions during the process to address challenges that came up. A questionnaire took about two hours and thirty minutes to complete.
- Analysis of the field data has commenced towards writing a draft paper which will be sent out for publication before June 2020. The work has been presented to senior researchers at ZEF three times, with Prof. Joachim (Principal Supervisor) in one of the presentations.

Figure 32. Northern region (NR) research assistants training. Similar trainings were conducted in the Upper East and Upper West regions. Photo credit: Shaibu Mellon/IITA.

Activity 4.1.2: *Map and assess relevant stakeholders to establish dialogue for the exploration of mutual synergies for scaling delivery of validated technologies.*

Sub-activity GH4121-19: Utilize ICT and GIS tools as a means to share information (agronomic, climatic, and market services) and scale-out Africa RISING technologies in collaboration with strategic partnerships in the region

During the reporting period, the **MWANGA Platform,** supported Africa RISING activities through dissemination of key messages to farmers. MWANGA stems from a Swahili word meaning to "enlighten or provide light." Currently, the platform has a membership of 300 farmers within the three regions of Northern Ghana. This allows farmers to share information and improve their decision making about which crops to grow, when to grow them, and where to sell them. The interactive platform provides a direct linkage to market outlets that offer reasonable prices for farmer products, keeping farmers aware of weather forecasts, appropriate times for fertilizer applications and weeding practices to maximize their yields. It allows farmers to send and receive information and feedback related to buying or selling of farm inputs; weather forecasts; and other information to boost farmer profits and make farming profitable. The platform also provides farmers with information about when project activities would take place—such as meetings, training opportunities—and provides a channel for agricultural extension agents, already on the ground, to offer subsequent advice to farmers. A sample of the messages shared in March 2020 to 300 recipients (180 males and 120 females) last month was about agronomic, climate services, and market information (https://app.esoko.com/).

During this reporting cycle, a crop planning decision matrix was shared with farmers in all three regions with extension workers. This work is being prepared for a publication but some of the results for the cropping calendar matrix are shared in Figure 33. The KASA analysis results will be shared in the next reporting cycle.

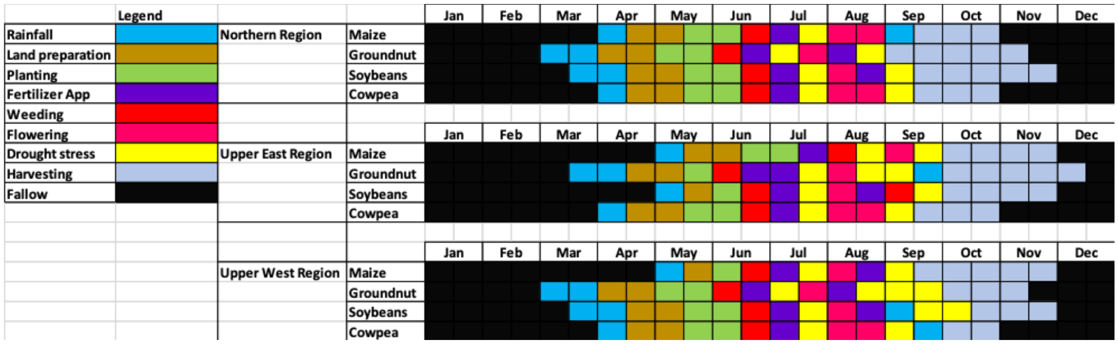

Figure 33. Cropping calendar decision matrix for the Northern, Upper East, and Upper West regions.

Output 4.3. *A framework for monitoring and evaluating technology adoption, and technology-associated risk accessible to the project team and scaling partners*

Activity 4.3.1: *Monitor & modify the progress of the technology adoption process towards scaling.*

Sub-activity GH4311-19: Matching agricultural technologies to farms and their context (Lead Institution: WUR)

This sub-activity provides a brief update on FarmMATCH work. A software engineer has been working with researchers of IITA and IFPRI to prepare data from ARBES and GIS maps, and analyzed these data for their use in FarmMATCH. For the testing of the FarmMATCH algorithm we have converted the ARBES data files for Ghana into a relational database (RDB). Variables were selected from this RDB and combined with GIS-based spatially explicit socioeconomic and biophysical data. The combined dataset was used to test the matching of selected technologies. For testing purposes, we derived the technologies from the ARBES dataset. Moreover, we created artificial technologies to test the effectiveness of matching algorithms and the effects of the different data sources and attributes on the matching result. The testing and further development of the matching algorithms is ongoing. The combined RDB database has been shared with other project researchers and can be used to parameterize a large number of farms in a whole-farm model for further analysis. A FarmMATCH prototype application was developed to mimic the functioning of the technology matching for advisors on farms. In this app the user (advisor) can enter a small set of farm and household specific data and receives the probabilities of the suitability of a number of technologies in the user interface.

Sub-activity MA4312-19: Assess the impact of Innovation Platforms on SI technology uptake in Africa RISING interventions communities (Lead Institution: AMEDD)

Analysis, interpretation, and discussion of achievements

The perception of farmers on IPs and their impact on knowledge transfer and the adoption of technologies availed by the research teams were evaluated. Participatory assessment of district and municipal IPs was conducted in Mpessoba and Ngolonianasso. We used FGDs and individual interviews to understand how IPs have influenced farmers' practices and livelihoods in the intervention communes. Discussions were held with stakeholders on the strengths and weaknesses of the platforms in addressing farmers' concerns, their knowledge gaps, and access to technologies.

The participatory analysis of the IPs indicated that most farmers perceived IPs as a space for exchange and co-learning. Both at district and community levels, the IPs set-up in Africa RISING target villages contributed to share knowledge among members and increased their access to innovations and capacity building. Their implementation tightened the links between farmers from different villages and different resource endowments. They also succeeded in increasing the bargaining power of women farmers', and their inclusion in decision making and agricultural research. Further details on this sub-activity will be provided in the final report.

Sub-activity MA4313-19: GIS mapping of implemented technologies across different agro-ecologies and gender influence in technology adaptation and use in Bougouni and Koutiala districts of Mali (Lead institution: AMEDD)

Technology adoption level varied from one location to another (results for Koutiala shown in Fig. 34). Based on the FGDs conducted in communities for both Koutiala and Bougouni districts, among the factors limiting technology adoption was lack of knowledge or skills in the farmers' household (27% in Koutiala, N = 30; and 22% in Bougouni N = 30). GIS tools were used for mapping the implemented technologies across different agroecologies and demographic settings to help evaluate adoption practices.

Innovative technology adoption analyses showed that organic manure was the most adopted technology in all targeted villages. On the other hand, aflatoxin control technology was the least adopted technology. The reasons for that can be the in situ availability at reasonable cost for organic manure and the fact that aflatoxin control is relatively new in the study area. Organic manure was adopted in all villages by 81% to 100% (Koutiala) and 81% to 96% (Bougouni). The contour bounding (CB) was adopted by 46% to 86% in Koutiala district, while it was adopted by 65% to 87% in Bougouni district. Integrated veterinary care was also well adoption in several villages. In 2019, several variations were observed in the technology adoption status. Throughout these variations, it was observed that the technologies with immediate impact on the living conditions of household had a rapid and constant adoption status (cf. family nutrition). However, an in-depth research is required to conclude the dynamics of technology adoption variations in the two agroecologies over a longer term.

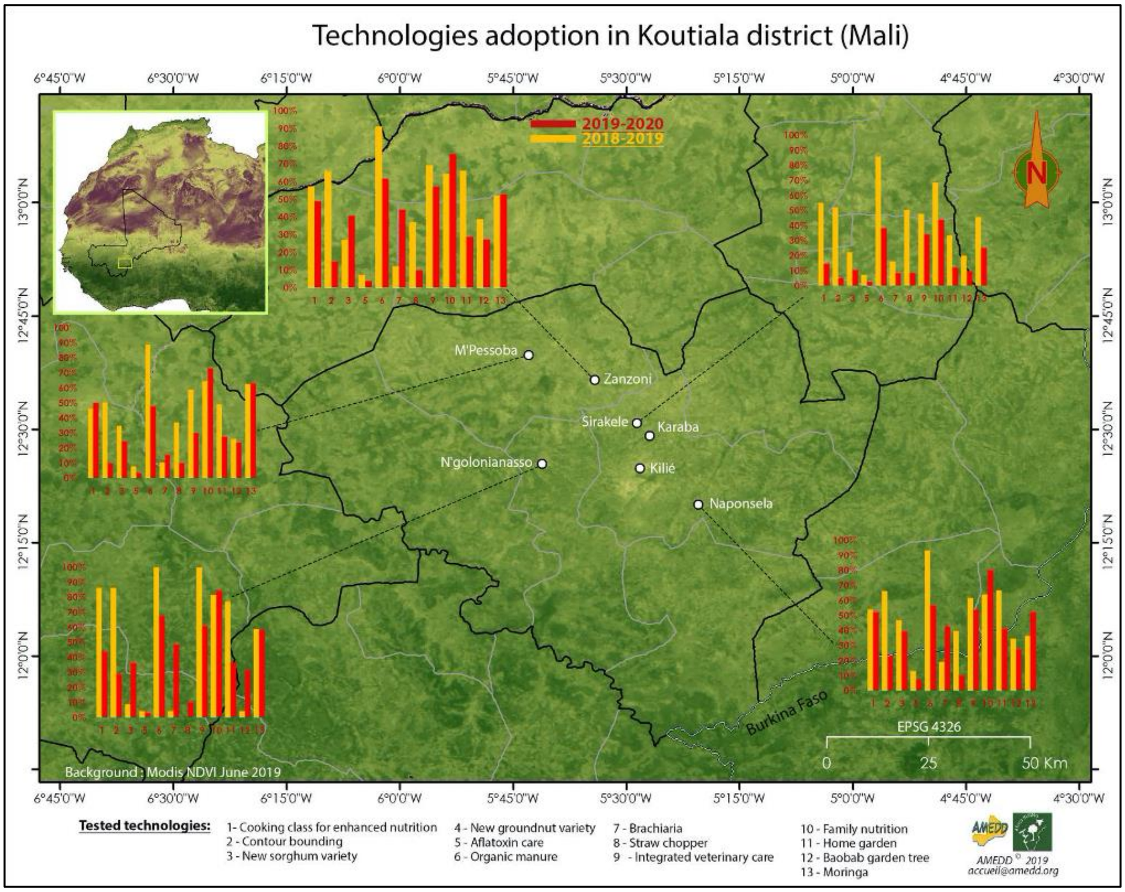

Figure 34. Technology adoptions status in Koutiala District.

Challenges encountered and mitigation measures

- While IPs at the district and commune levels were highly successful to raise farmers' awareness and increase their access to innovations, IPs faced several challenges. A serious challenge for IPs is their constant dependence on donor funding for functioning which impacts the frequency of IP meeting. To strengthen the existing IPs there is a need to increase awareness campaigns to the relevant institutions (for example, ministries of agriculture and regional or district level research offices) and engage the private sector organizations such as banks and agricultural input dealers.
- The main agronomic constraint faced in 2019/2020 was the heterogeneity of the soil for trial operation especially in the M'Pessoba Technology Park where the plot was previously used for agronomic trials with different rates of fertilizers. Future research needs to look at the impact of residual nutrient on variation of crop productivity.

Partnership/linkages with other projects

Partnerships and linkages with other projects were made possible through sharing research protocols and utilizing technology parks to disseminate validated technologies. The following partnerships were observed with Africa RISING project during the reporting period.

- The seed of sorghum varieties (Soubatimi and Peke) utilized under Africa RISING were developed through the McKnight_Networking4Seed project. This will ensure the availability of seed to farmers who are validating the technology in Africa RISING intervention villages.

- The planned activity on efficient feed utilization through improved feed troughs was based on success stories of a similar intervention by the Africa RISING project in Ethiopia. Results from monitoring of the use of the improved feed troughs in four sites in Ethiopia showed that it saved 27% of the cereal and legume residues offered to the animals compared to the traditional feed troughs. Preliminary results from the data collected on the use of the improved feed troughs in Koutiala March/April 2019 showed that it saved between 10 and 15% of the cereal and legume residues offered to the animals compared to the traditional feed troughs.

Lessons learned

- Farmers demanded the CB technology as its immediate effect on crop yield and biomass increment was fast, starting with the first year of its implementation in 2015. The CB technology reduces runoff and erosion, recharges soil water table, increases soil moisture, and consequently increased crops yield and growth of trees.
- Soil and water conservation was improved using CB technology. Growth of fast-growing nitrogen fixing trees species showed better development and better environmental conditions by mitigation greenhouse gas through carbon sequestration. Farmer exchange visits and training permit the extension of innovation systems to rural areas. The advantages of these technologies must be sustained in the households of the study area so that they can continue after the project lifetime.
- Construction of improved feed troughs can be an income-generating activity for the youth but to make it profitable local materials should be used for construction. Therefore, there is a plan to construct improved feed troughs using only available local materials.
- Micro-dosing and organic manure application were very useful to increase the productivity and profitability of sorghum production in Sudanian agroecological zones of Mali. These technologies have the potential for scaling to other agroecologies as adaptation strategies to reduce the impact of climate change.

Success stories

Story 1: *Malimark* is a local NGO engaged with development projects in Mali. Its director was among those who was invited during the Africa RISING farmers' field days in October 2019. After her visits in both Bougouni and Koutiala technology parks she made a commitment to support the smallholder farmers to gain access to dual-purpose sorghum varieties. She supported farmer organizations to produce Soubatimi seed and later farmers were linked to seed companies and agro-dealers for seed commercialization. In 2019, *Malimark* coordinated Soubatimi certified seed production with *Camara Semence* and farmers seed cooperatives with a total of 38.6 ha planted. From these activities over 50 MT of Soubatimi seed is available for the 2020 agronomic season. According to the Seed company, "*Camara Semence*", Soubatimi is an early maturing variety and the fodder is much liked by livestock; the average grain yield obtained was 2.3 MT/ha. In addition, the seed cooperatives in Bougouni, under *EUCOR* supervision, started producing Soubatimi seed and a total of 10 ha was planted in 2019 to produce over 15 MTof certified seed available for the 2020 agronomic season.

Story 2: The improved feed troughs could be a success story in the near future based on the general enthusiasm shown by the farmers in the intervention communities. Farmers who were not involved in piloting the technology have approached the project team to request the improved troughs. Besides, the Africa RISING evaluation team also received positive feedback from the farmers during their visit to Sirakele in September 2019 where some units of the improved feed troughs were constructed by the project.

Communication and knowledge sharing

The main communication channels supported during the reporting period were:

- Wiki internal workspace: http://africa-rising-wiki.net/Home
- Project updates on the program website: https://africa-rising.net/
- A Yammer network with internal updates
- Photos: https://www.flickr.com/photos/africa-rising/
- Repository: https://cgspace.cgiar.org/handle/10568/16501

The stories listed below were published and disseminated to stakeholders concerning different project activities and outputs during the reporting period.

- Most smallholders diversify crops by default, why governments should always consider this in policy (13 March 2020)
- Serious gaming offers insights into land use decision dynamics in northern Ghana (12 February 2020)
- Sustainable intensification: Is a systems perspective essential for integrated crop-livestock systems? (16 January 2020)
- Best of both worlds: Intercropping Napier grass with legumes boosts food and livestock productivity in Ghana (2 December 2019)
- Africa RISING at Tropentag 2019 (14 October 2019)
- Review team commences visits to Africa RISING activity sites (2 October 2019)

The following meetings and events were held during the reporting period. The communications team supported some of these meetings and events through materials preparation, facilitation, etc.

- 12–14; 19–21 February 2020: Formation of Innovation Platform and small ruminant value chain analysis (Upper East and Upper West regions)
- 06 February 2020: Progress Workshop in Tamale, AR - West Africa (Ghana) Partners
- 03–05 February 2020: Training on Container Gardens in Tamale by the World Vegetable Centre
- 30 January 2020: Progress Workshop in Bamako, for AR - West Africa (Mali) Partners
- 19–24 January 2020: Data collection on efficient feed utilization through the use of improved feed troughs in the Upper East region of Ghana
- 08–18 January 2020: NUTRITION—Inauguration of Care Groups in the Upper West and Northern regions of Ghana
- 18–28 November 2019: Reinforcement of Small Ruminants Value Chain in the Upper East and Upper West regions of Ghana
- 05–06 November 2019: Farmer Field Days in AR Mali sites
- 08–18 October 2019: Farmer Field Days - Assessment of validated agronomic technologies by Africa RISING farmers in the Northern, Upper East and Upper West regions of Ghana
- 03 October 2019: Farmer Field Day on Feed/Food production
- 15 September–21 September 2019: Internally Commissioned External Review Team visit to project sites in Ghana & Mali

Selected reports and publications

The following peer reviewed journal articles and reports were published by the project team during this period.

Peer reviewed journal articles

- Traore, K. and B. Zemadim. 2019. Soil erosion control and moisture conservation using contour ridge tillage in Bougouni and Koutiala, southern Mali. Journal of Environmental Protection 10: 1333–1360.
- Michalscheck, M., J.C.J. Groot, G. Fischer, and P/ Tittonell. 2019. Land use decisions: By whom and to whose benefit? A serious game to uncover dynamics in farm land allocation at household level in northern Ghana. Land Use Policy
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Project logframe summary of the Ghana and Mali workplans

We present the outcomes, outputs, and activities of the Africa RISING West Africa Project Phase 2 using a logframe overview that can be accessed at this link: http://africa-rising-wiki.net/images/0/06/Project_logframe_overview.docx

Planned milestones, reasons for deviation from milestone, and actual achievements

This section provides updates from partners on outputs from different partner institutions' planned milestones and deliverables which were planned from October 2019 through March 2020. The detailed tabular matrix can be accessed at this link: http://africa-rising-wiki.net/images/1/1e/Annex_deliverables.docx